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EDITORIAL NOTES

O.R. AND THE ROADS

TRANSPORT probably provides more opportunities for operational research than does any other industry. DR. R. J. SMEED'S paper in our last issue describing the Road Research Laboratory's investigations into the driver's behaviour, and the report of the meeting on "Men and Machines in Transport" given in this issue, raise some interesting points. It is encouraging for those with a belief in human nature to see that Dr. Smeed's findings can be explained on the assumption that the driver normally acts as a sensible adult; that is to say, he reacts to any particular situation as the situation demands rather than by a slavish adherence to routine regulations. This suggests that traffic regulations may be at their best when they take the form of warnings and advice rather than when they are didactic.

There is another feature of this. Research into accidents in industry shows more and more the importance of the frame of mind of the individual in the causation of accidents. The man with a sense of grievance may have an accident in circumstances which would not have led to any accident had he been in good humour. It would appear to be of great importance that drivers and pedestrians should not be under a feeling of grievance towards those responsible for the administration of the roads. There is no more fruitful source of grievance than restrictions which are clearly misjudged or which serve no useful purpose. Many such regulations are still being made by traffic authorities. For instance, the system which is becoming common whereby the sign "No Waiting" is put in such a way that the motorist has to adopt some such rule as follows in order to comply with the regulations: "if the words 'No Waiting' are visible, waiting is allowed; if a blank sign is visible, look on the other side; and if 'No Waiting' is written there, then no waiting is allowed." There

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are other regulations which appear to serve little purpose other than swelling the coffers of the local police court ; for example, the erection of "Halt" signs at intersections where there is sufficient visibility along the major road to make a halt unnecessary. There are others which appear to serve no useful purpose at all, such as the squaring off of egress from main roads into minor roads on the near side, which simply causes a turning car to slow down and cause obstruction of the flow of traffic into the main road.

On the other side of the picture it seems probable that some part of the success of the zebra crossing is due to the fact that drivers appreciate that these are the results of genuine thought and are based on sound experimental findings.

It would appear that very great benefits on road safety might result if new regulations and alterations to roads were based, and were known to be based, not on the whim of the local surveyor, but on the results of properly conducted research. The Road Research Laboratory is already undertaking operational research in a wide variety of problems and it may be hoped that very great benefits will result. Nevertheless, from the nature of their position they can deal only with problems of general interest. At a recent meeting of the Institute of Transport a paper was read by MR. F. A. A. MENZLER, who described work which is being done by London Transport. London Transport is the largest single user of London streets. Many of the other users are, however, attached to organised associations of one sort or another, and, as one speaker commented, it is remarkable that none of the motoring organisations appear to be undertaking any form of operational research for the benefit of their members.

OPERATIONAL RESEARCH CLUB

The Committee recently met to consider the problem of the increasing number of young operational research workers who are at present effectively denied membership of the Club by the imposition of a membership ceiling.

At the same time the Committee took note of the increasing interest in the Club's proceedings and considered a suggestion that steps should be taken to ensure publication, wherever possible, of papers read to the Club, though not of the subsequent discussion.

It was agreed to propose that the name of the Club should be changed to "The Operational Research Society," that the membership ceiling should be lifted, but that the same careful scrutiny as hitherto of the qualifications of applicants for membership should be continued. Steps should be taken to secure the publication in the Operational Research Quarterly of papers read at our meetings.

It was particularly hoped that these changes could be made without affecting the present informal nature of the Club's proceedings and without, at least in the first instance, moving from our present meeting place, though some rearrangement of the seating might be necessary.

The Honorary Secretary is preparing a revised Constitution to embody these aims, which will be submitted to members in due course.

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MEN AND MACHINES IN TRANSPORT SYSTEMS

This subject was discussed at a joint meeting of the Ergonomics Research Society and the Operational Research Club on February 13th. Of the three papers presented for discussion, "Some Factors Influencing the Road Behaviour of Vehicle Drivers" *by* R. J. SMEED *(Road Research Laboratory) was published in our last issue (Operat. Res. Quart. 3* [4]*). The other two, respectively by* R. L. MOORE *(Road Research Laboratory) and* R. E. F. LEWIS *(Applied Psychology Research Unit, Medical Research Council) are given here, very much abridged.*

PEDESTRIAN CHOICE AND JUDGMENT *

by

R. L. Moore

In 1951 some 2,400 pedestrians were killed and 57,000 injured on the roads of England, Wales and Scotland. There is therefore good reason for enquiring into the factors which influence the behaviour of pedestrians, and this paper is a summary of some of the work carried out by the Road Research Laboratory on this subject. Other investigations concern roads, vehicles and drivers.

The chance of a person becoming a pedestrian casualty varies with age and sex.

TABLE I

Pedestrian Casualty Rates Per 10,000 Persons Per Year
(England, Wales and Scotland, 1949)

Age Group	Pedestrian Casualties per 10,000 Male	Female
Under 10 years ...	3.3	1.9
10-20 years	0.9	0.8
20-30 years	0.5	0.4
30-40 years	0.5	0.4
40-50 years	0.6	0.5
50-60 years	0.9	0.8
60-70 years	1.5	1.1
70 and over ...	2.4	1.5

Nearly 80 per cent. of those killed are children and old people. The liability for men is greater than that for women. The safest pedestrians are women between 20 and 40 years.

When Pedestrians Cross the Road

A person standing at the side of a busy road which he wishes to cross has to look at traffic in both directions and make his own estimate of when it is safe to cross. His estimate is normally a correct one, but in about one case in a million or so he makes a disastrous mistake. What are the factors which influence his decision of when it is safe to cross?

In order to answer this question a study was made of the movement of vehicles and pedestrians at a pedestrian crossing. A crossing which had a central refuge was chosen because the pedestrian's choice, to cross or not to cross, is simplified at such a place. The roadway was

* Original paper given to the British Association, Psychology Section; Belfast, September, 1952.

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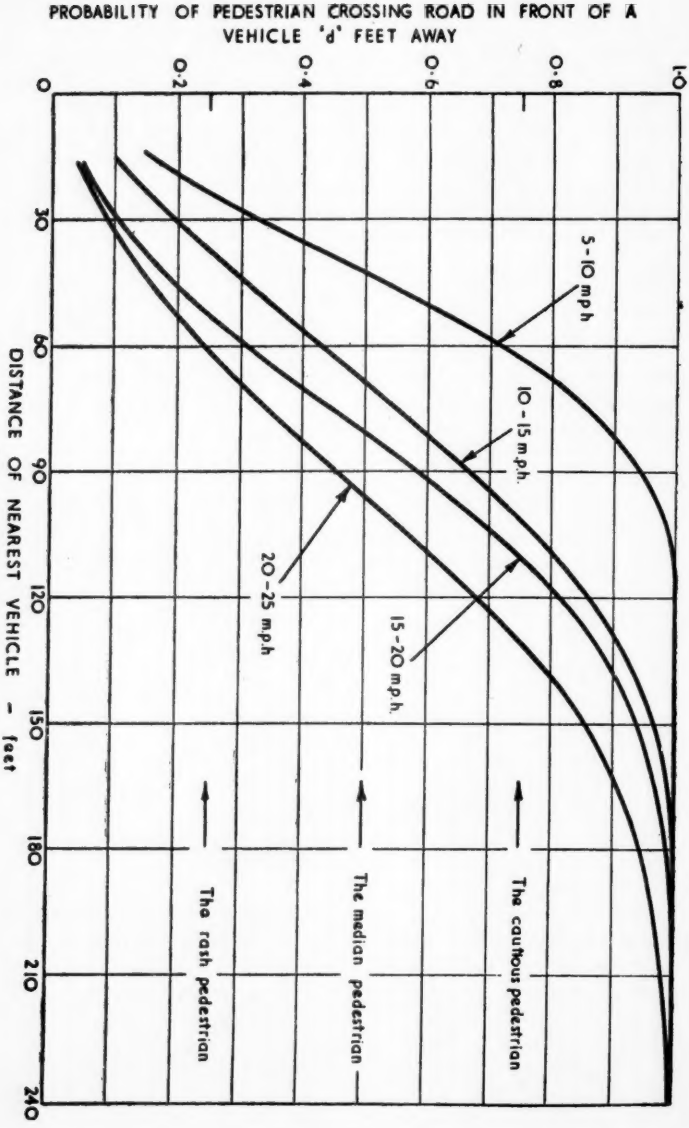

Fig. 1.—Pedestrian Judgment.

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marked some distance from the crossing at several places, and the passage of each vehicle over each mark was recorded on a moving chart. The arrival of a pedestrian at the kerb and his subsequent pause and eventual movement across the road were similarly recorded.

Fig. 1 shows the probability that a waiting pedestrian will cross in front of moving vehicles at given distances and speeds. Seventy-five per cent. of people will cross in front of a vehicle 60 feet away moving at 5-10 m.p.h., but if the vehicle is travelling at 20-25 m.p.h. only 25 per cent. of pedestrians will risk crossing. This suggests that pedestrians are concerned primarily with a time-gap and not a distance gap in the traffic.†

In Fig. 2 the time taken by the pedestrian to move across half the carriageway from the kerb to island has been plotted against the expected time of arrival of the next approaching vehicle. It will be seen that when the vehicle is less than 7 seconds away the pedestrian, realizing his danger, increases his speed across the road.

The pedestrian's choice of a suitable time interval in which to cross the road rather than a distance gap is an economy of his time. At the crossing studied it has been estimated that if all pedestrians waited for a gap in the traffic of at least 100 feet before crossing the road, the average loss of time by waiting at the kerb or refuge would be 9 seconds per pedestrian; the actual pedestrian delay is only 3 seconds. Moreover, this threefold increase in delay would not necessarily make for greater safety because it is known that there are numbers of vehicles on the roads today, with poor brakes, travelling at speeds such that they cannot stop in 100 feet. There is therefore some indication that economy of time or effort plays an important part in determining pedestrian behaviour, two further examples of the operation of some such principle will be given later.

Where Pedestrians Cross the Road

A count was made, in 1948, of the pedestrian flow across 15 miles of busy streets in West London (Table II).

TABLE II

Pedestrian Flow Across 15 Miles of London Streets
(1949—Before Zebra Marking)

Crossing place	Number crossing		
	Per hour x 1,000	Per hour of foot run of road	Relative Risk*
Uncontrolled pedestrian crossing ...	13	14	0.9
Ditto, with a refuge	13	25	0.7
Light-controlled pedestrian crossing	3	12	0.5
Ditto, with a refuge	7	26	0.4
Elsewhere	59	1	1.0

* Risk, i.e., $\frac{\text{Daytime accidents}}{\text{Pedestrian flow}} \div \frac{\text{Daytime accidents elsewhere}}{\text{Pedestrian flow elsewhere}}$

† In obtaining these curves it was assumed that each pedestrian has his own critical distance gap for vehicles of a particular speed range. If an approaching vehicle is nearer than this critical distance the pedestrian will not cross, if it is further away he will cross. It has also been assumed that those critical distances follow the normal (Gaussian) law of errors over the population.

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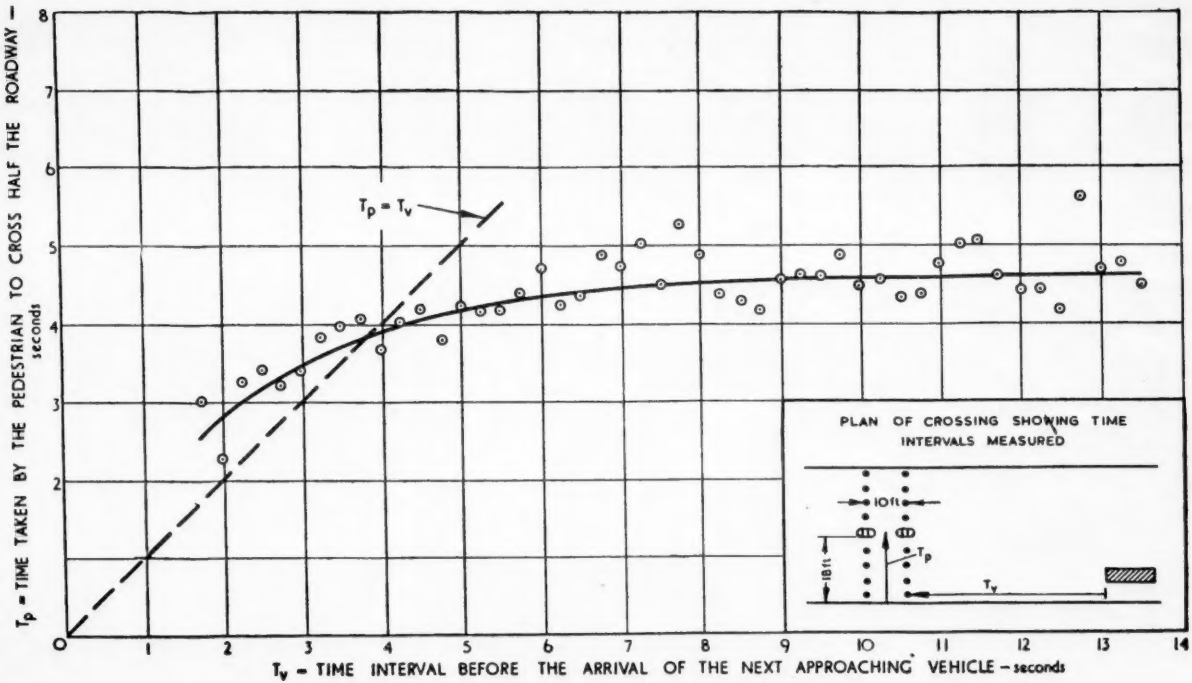
T_p = TIME TAKEN BY THE PEDESTRIAN TO CROSS HALF THE ROADWAY – seconds
$T_p = T_v$
T_v – TIME INTERVAL BEFORE THE ARRIVAL OF THE NEXT APPROACHING VEHICLE – seconds
PLAN OF CROSSING SHOWING TIME INTERVALS MEASURED
10ft
18ft
T_p
T_v

Fig. 2. —Pedestrian celerity.

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Crossings with refuges with or without lights have the greatest density of pedestrian flow. Suppose the risk of crossing the road not at a special road feature equals 1 (the actual risk is about 1 in 106) it is seen that uncontrolled and light-controlled crossings are safer places to cross than elsewhere. The difference for the uncontrolled crossing without a refuge is so slight it may be due to chance; the reduction of risk at other crossings is statistically significant. It should be mentioned that the investigation on the relative risk of crossing the road at an uncontrolled pedestrian crossing and elsewhere was done before the introduction of zebra markings.

If pedestrian crossings as a whole are safe places to cross the road it is necessary to find ways of attracting pedestrians to crossings. The zebra pattern was chosen as a result of experiments carried out on a model road to find ways of making the crossing more conspicuous to the driver. The great improved visibility of the crossing to the pedestrian was a welcome result, but not the main purpose of the marking.

Experiments to find the effect of such markings on pedestrian behaviour were carried out in 1948-49; there was then no special publicity and any changes can be attributed to the marking only. The first studies were made in daylight at six selected crossings. Counts were made of the number of pedestrians crossing the centre longitudinal line of the roadway within 20 yards of the crossing, and also those crossing between the lines of studs marking the crossing. These observations were made before and after the striping at the same time and on the same days of the week to eliminate as far as possible variations in the total number of pedestrians and in the amount and type of vehicular traffic. The observers were stationed either in a vehicle near the crossing or in a room overlooking the site (Table III).

TABLE III

The Effect of Zebra Marking Without Propaganda
(6 Crossings London Area, 1948)

Class of pedestrian	Percentage using crossing in prescribed manner	
	Before marking	After marking
Men	45	53
Women ...	63	69
Children ...	69	81

The proportion of pedestrians using the crossing was greater after striping, and women made more use of crossings than men, and children more than women.

In 1949 an experiment was carried out to find the effect on road user behaviour of zebra marking plus propaganda—a nation-wide pedestrian crossing week. Road user behaviour was observed at 50 crossings at various towns in England and Wales before and after. Half of these crossings were zebra marked just before the propaganda week. The effect of the propaganda and also the propaganda plus zebra marking on the behaviour of pedestrians is shown in Fig. 3. Propaganda appears to have a transient effect, but when reinforced

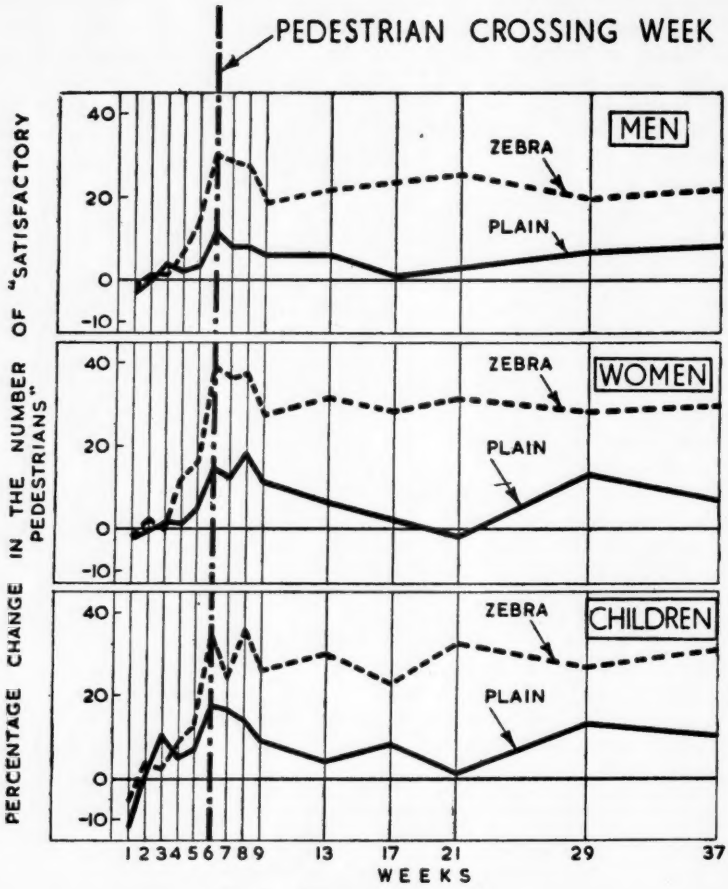

Fig. 3.—Effect of propaganda.

by zebra marking the effect was greater and more permanent.

In 1951 zebra marking was made universal at all uncontrolled crossings, and there were slight changes in the regulations governing the priority of pedestrians. These changes were heralded by the Press as giving a new charter to pedestrians. The zebra marking was boosted for many weeks; it became the stock-in-trade of the cartoonist and a music-hall gag. There was an immediate increase in the proportion of pedestrians using the crossings, the effect being visible even to the casual observer.

Pedestrians frequently have to go out of their way to use pedestrian crossings. They walk to the crossing, cross the road and then proceed on one of two ways; either they walk along the opposite pavement

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in the same direction along the road—thus making a Z movement, or in the opposite direction, thus making a U movement. Only a quarter of those crossing the road make U movements. It is obvious, too, that pedestrians are much more likely to use a crossing when it can be done with little inconvenience. There is close correlation between traffic flow and pedestrian crossing usage, suggesting once again that the pedestrian economises in time or effort whenever possible.

An experiment was carried out to determine the effect of the presence of a policeman on pedestrian behaviour. At intervals during the course of observations it was arranged that a policeman should stand on the pavement a few yards from the beacon and do nothing except watch the crossing. It was found that with the policeman present the proportion of men using the crossing increased significantly. There was no such change in the behaviour of women. A similar difference between the sexes was found during the course of observations at other crossings when a policeman held up traffic from time to time to allow pedestrians to pass. It should be stated that a higher proportion of women used the crossing without a policeman than men did with. These results need confirmation and it would be interesting to know if the effect of a policewoman would be different from that of a policeman.

Subways and Bridges

One safe way to cross the road is by a pedestrian subway or a bridge. But these are expensive items ; a cheap bridge, for example, may cost £2,000 and a subway as much as £20,000.

We have up to the present made observations of the pedestrian usage of three subways and three bridges. One was a junction on the main London-Bath road at a place where large numbers of factory workers have to cross morning and evening, during peak traffic hours. From the pattern of pedestrian flow across the road before the subway was opened and after, it was clear that the chief effect was to divert underground those people whose original path followed the line of the subway ; that is, pedestrians whose journey time was not increased much by using the subway.

It is important for a highway authority to be able to predict how much use will be made of a proposed subway or bridge, and we have collected some data on this. Pedestrians cross the road between two points A and B ; they will be delayed by the traffic by an amount which can be measured. If a subway or a bridge is built at C, what proportion of pedestrians will use it? Let us assume that pedestrians choose the path requiring least time. Let the ratio of the time required to use the subway or bridge to the total time to cross the road be R. It is reasonable to suppose that if R is very large—if, for example, the subway is half a mile away—no pedestrians will use it ; if, on the other hand, R is less than unity, that is the subway or bridge is the quickest route, then nearly all pedestrians will use it.

We wish to find, however, what percentage of pedestrians will use the safe path for conditions intermediate between these two extremes. A very tentative result has been obtained by lumping together values obtained at subways and bridges of different construction and at very different sites. Roughly 80 per cent. of people will use the safe path if it takes the same time as the path across the road. It would appear that in general to obtain a high subway usage, some device to increase the inconvenience of the path of pedestrians at road level will have to be arranged. If by the use of guard rails, for instance, the path across the road takes one-third as long again as the safe alternative, then all pedestrians may be expected to use the safe path.

In conclusion, therefore, we are attempting to find the conditions where the risk of road accidents is greatest to pedestrians, and by studying the factors which influence choice and judgment, we hope (without his necessarily being aware of it) to help the pedestrian to form safer patterns of behaviour.

SOME MEASURES OF DRIVER BEHAVIOUR

by

R. E. F. Lewis

A number of factors affecting driver behaviour are under examination at Cambridge, but this paper is mainly concerned with the driver's ability to repeat his performance from day to day under the same conditions. It also deals with signals by drivers of motorcycles.

For our experiments we use a popular 10 h.p. car, easy to drive, which has two single shot cine-cameras mounted: one faces forward photographing the road and traffic situations ahead, with the dashboard in the field of view of the camera. This arrangement enables us to record simultaneously, traffic situations, acceleration, speed, time and lateral acceleration. Also on the dashboard is a small illuminated display which shows the time and distance in a selected gear, clutch pedal movement and brake pedal movement.

The rearward facing camera, which views across and down towards the nearside of the road, records distance from the verge and passing distance. There is also a measure of mirror attention, which is achieved by the driver pressing a small ring quadrant beneath the wheel which moves the mirror through about 15 degrees when he wishes to look through the rear window to view to the rear. The two cameras are synchronised and can be fired in terms of time or distance—a five-yard distance sample is usually adequate.

In experiments to find out if drivers are consistent in their day to day behaviour, average drivers were asked to drive the experimental car on a disused aerodrome under three different road conditions without traffic. Nine drivers acted as subjects for the experiment, and for 30 to 45 minutes before the test familiarised themselves with the car. Of the subjects initially tested, six were re-tested ten days later under the same conditions of test, the remaining three after

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ten weeks had elapsed.

Sample measurements of speed and acceleration were recorded at two-second intervals for each condition, and a comparison was made between conditions for the two occasions on which the subjects were tested. It was found that some drivers showed a marked consistency in their choice of speed and acceleration. Those who were most consistent between occasions in any one road situation, were likely to be consistent in other situations within the limits of the experiment. Of the three subjects re-tested after an interval of ten weeks, two showed a marked consistency in their choice of speed and acceleration in all situations.

The Chief Driving Instructor of the Essex Police Advanced Motoring School then selected for us ten very experienced drivers and ten other drivers whom he considered to be rather poor or below average.

The drivers were required to negotiate four very sharp corners: two to the right, and two to the left. They covered roughly half a mile in their approach to the corners, and for a distance of 150 yards before and after the corners speed and acceleration were sampled once every five yards of distance covered. The test was repeated for each subject six weeks later, and the driver was then instructed to treat the corner as in the initial test. None of the drivers were expecting the re-test.

Fig. 4 shows the acceleration patterns for one driver in each group, and for each subject you see two of the corners with the test and re-test curves shown. The horizontal centre line indicates zero acceleration, and the vertical centre line the corner. The skilled driver certainly appears to be the more consistent between the occasions of test. The results may also be interpreted in terms of decisions made: the skilled driver approaches the corner making a decision in terms of an increasing deceleration, whereas the unskilled driver quite often makes a decision which he then reverses.

To eliminate the factor of the specialised training that police drivers get, we hope shortly to begin trials in which we will test, under the same conditions, skilled but untrained drivers.

There are many skills that can be examined from this point of view, and I would like to mention one or two points that I would be very interested to see considered.

I would like to know whether, if given the same weather conditions, the skilled aircraft pilot will produce scores with a smaller scatter than the unskilled pilot, when the vertical acceleration is measured at the point of impact on repeated landing trials; or perhaps, whether the skilled bus driver will drive away with repeatedly similar accelerations when leaving a bus stop.

I think it probable that the measures used must be carefully selected and should be part of the skill over which the worker or operator has no easy control.

Mr. Lewis then described experiments to evaluate a turning signal indicator for motor-cycles, which resulted in the development of an

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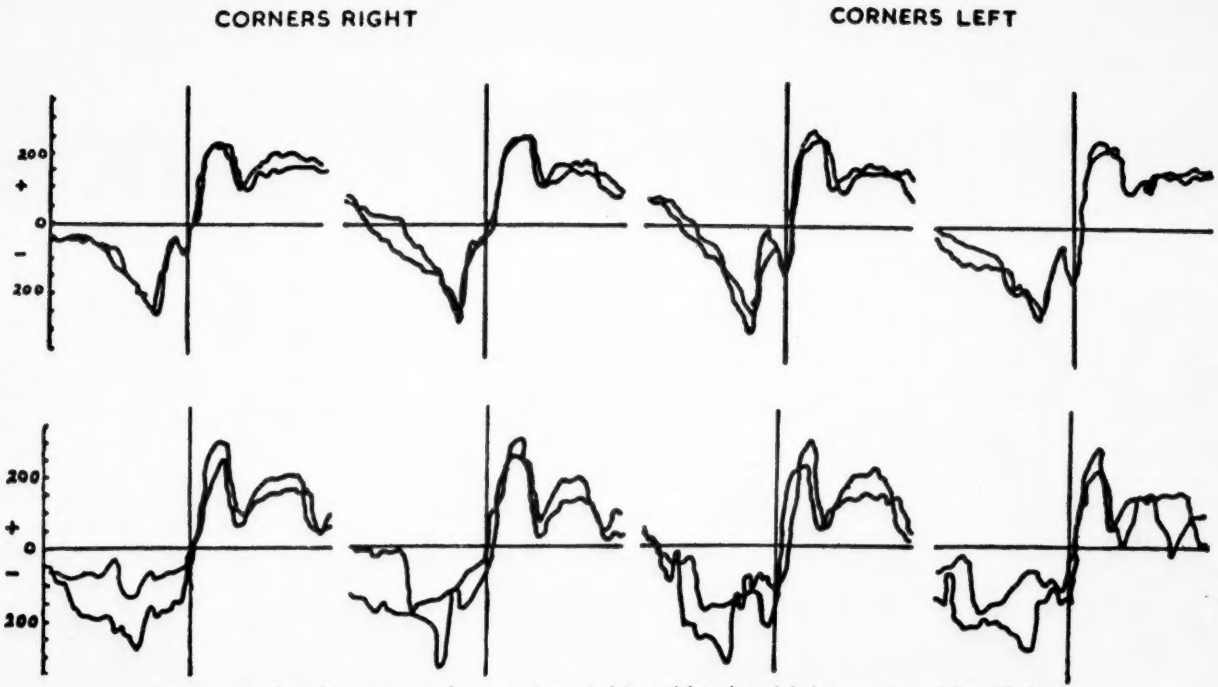

Fig. 4.—Acceleration patterns for experienced driver (above) and below average driver (below).

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"experimental trafficator" to provide a greater lateral separation of turning signals, rear light and stop light than that provided by the manufactured turning indicator under test. At night, results from the experimental trafficator were nearly twice as good as those from the turning indicator, and both were, as might be expected, better than hand signals.

A further series of trials attempted to reproduce the conditions which a following driver, in fact, experiences. A turning signal was illuminated for a period of one second every 25 yards of distance covered. This to some extent reproduced the conditions of a driver following a rear light, and then seeing a signal go on in relation to that light, the rear light being used as a point of reference. Immediately an improvement was noticed. This arrangement could be associated with a flashing light display as opposed to a steady light display.

Mr. Lewis concluded by showing a film of hand signals observed at Cambridge, and contrasted those given by police drivers. He suggested that it would be valuable if a comprehensive series of signals could be produced to operate effectively at the touch of a switch. Signals were usually made at a time when drivers were concentrating closely on what they were doing and were about to do. Any advance which made for easier signalling and easier recognition of signals would help to simplify the driving task.

DISCUSSION

DR. W. F. FLOYD (Middlesex Hospital Medical School: Joint Honorary Secretary of the Ergonomics Research Society) opened the discussion. He commented that he looked at the subject as a physiologist who recognised that it had important psychological aspects.

He considered the problem of road transport in relation to the human ear and eye, concerned chiefly with human reactions to abrupt changes in an ever-changing visual display. He questioned whether the elements under engineering control were always matched to the visual system; for example, were traffic lights placed and timed to give the driver the best view of the signal at the earliest possible moment, having particular regard to braking systems? This problem was also important from the pedestrian's point of view.

Commenting on the complexity of display, the speaker questioned whether consideration had been given to the measurement of the upper limit of the "order of complexity to which a human being can react both mentally and physically." Somewhat similarly, he thought that such devices as car radio might contribute to the overloading of the sensory system of the individual. The fact that radio affected hearing and the visual display affected sight did not make any difference to the fact that the co-ordination occurred in the central nervous system, and it was here that the overloading could occur.

Speaking physiologically and commenting on posture and movement, Dr. Floyd said he thought there was a good deal to be done by the re-design of seats and of windscreens and coachwork for control

and vision. The question of pedal travel and pedal pressure was also worthy of attention. The reaction time for depressing a pedal was of the order of 0.5 sec., and if even 0.1 sec. could be saved the difference in distance and safety would be considerable and valuable. He pointed out that research on this subject had been carried out during wartime in relation to fighting vehicles, but he did not know if anything parallel had been done in peacetime. A specific point that occurred to him was that heavy steering-wheels in goods and passenger vehicles were frequently mounted almost horizontally, and this could be shown to be wrong from the point of view of control and posture. In the summer the temperature in a driving cab of such a vehicle might easily reach 80° F. or more, thus providing an adverse local climate for the driver which could induce premature fatigue and increase the liability to accident. Controlled ventilation and possibly air-conditioning would seem desirable.

MR. BAYLY PIKE (War Office) described some experiments that had been carried out by the Army Operational Research Group on driving in convoy.

Much of the problem concerned the inability of the human eye to detect slight changes in distances between vehicles. Investigators had travelled many thousands of miles on convoys, recording intervals between vehicles, and speeds of vehicles at the back and front of the convoys. The same situations always caused bunching and opening up, with the consequent necessity for hard driving at the rear of the column.

There were two classes of remedy to consider: mechanical and organisational.

(a) Mechanical.—The fitting of a brake light reduced appreciation from 1.5 sec. to less than 1 sec. Mr. Pike observed that they had measured the time of transfer of a driver's foot from the accelerator to the brake pedal as being 0.3 sec. There was therefore another saving to be made by fitting the brake light to operate on the release of the accelerator pedal rather than on the depression of the brake.

(b) Organisation.—They had found in actual experiment with army vehicles that breaking up convoys into smaller "packets" was an almost complete answer to the problem. When a convoy of 30 vehicles was on the road, the rear vehicle's speeds varied from 0 to 40 miles an hour when the front vehicle kept up a steady 20 m.p.h. If the same convoy was broken up into six groups of five vehicles, it could cover its journey in the same time but would keep better order. The front vehicles could keep a steady 20 m.p.h. and the speeds demanded from the rear vehicles ranged between 12 and 27 m.p.h.

MR. F. L. SAWYER (Ministry of Civil Aviation) gave an account of some of the work in progress in his department. These problems related to ground control of air traffic. He thought that the increasing speed of aircraft made it possible that air traffic control would become necessary in all weathers. At the present time it was only necessary

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in bad weather. Air traffic control was based on information on the traffic pattern from pilots' reports and ground radar. A 'plane entering the country might pass through the hands of six or seven ground controllers in 20 minutes. This seemed complex, but was necessary because of the range limitations of radio and radar and the complex traffic pattern.

Man-machine problems in this field were therefore problems of communication machines; how they might be planned and used so that the best results might be obtained from the human operators.

MR. M. H. JOHNSON (Ministry of Civil Aviation) continued on the same theme by describing a study of possible application of automatic digital computors to the solution of these problems. He said that essentially an aeroplane being given a route was "a missile directed to miss a lot of moving targets." He had devised a means of "programming" an automatic computor to select one from various proposed routes fairly effectively. It was a problem to know how it could be used. An automatic traffic controller may take over only if this could be done without danger. This seemed to necessitate the operators being in possession of full knowledge of the situation. Mr. Johnson doubted if a man could monitor a machine satisfactorily in the circumstances. The less often the machine went wrong, the less capable the operator would be of taking over. He personally was inclined to think it advisable to devise a system whereby a machine could monitor a man rather than vice versa.

In short, it might be preferable to concentrate on devising a system wherein machines would give men facilities to use their own faculties to their best advantage rather than to remove the need to employ them.

MR. A. T. WILFORD (London Transport Executive) commented on Dr. Smeed's point on the persistence or otherwise of education in the use of pedestrian crossings. Fuel consumption by London Transport vehicles showed a sudden increase following upon the introduction of zebra crossings, but the trend did not persist, and during November, 1952, there was a decrease in consumption compared with a year ago. He asked if Dr. Smeed had any later evidence than had been put forward in his paper on the use of pedestrian crossings.

DR. SMEED replied that later indications were that the improvement was less than it had been, but use of crossings was considerably greater now than it had been before they were marked with the zebra stripes.

"Operational Research in British Industry" was the subject of a lecture by SIR CHARLES GOODEVE, F.R.S., to the John Hopkins University in the U.S.A. on April 7th. He also participated in the Case Institute 75th Anniversary Convocation at Cleveland on April 10th and 11th, where he joined Gwilym Price and K. T. Compton on a panel on "Operations Research—A New Approach to Complex Social Problems."

ABSTRACTS

Moe's Principle.

ARNE JENSEN.

The Copenhagen Telephone Company, 1952 ; 35 *pp. and* 123 *pp. of Tables.*

One of the main tasks in telephone administration is that of determining a number of channels, selections or registers by means of which desired call connections may be established within the boundaries of a telephone plant. This determination must be made, having regard to the expenses involved and the demand for telephone calls within the areas in question.

A theoretical approach to this problem is developed on principles suggested by the late Kai O. Moe for the determination of the cost function and optimum level of output. The results of this theory are then applied to telephone problems under specified conditions. Although here only applied to telephone plant embodying particular systems, the methods outlined are general and immediately adaptable to other systems and distributions.

p-Charts Improve Methods for Determining Downtime.

G. NADLER (Washington U.) and D. H. DENHOLM (Chase Bag. Co.).

The Iron Age, 27th November, 1952 ; **170** (22), 110-113.

The use of p-charts as developed for quality control is described as a method for studying downtime where readings are obtained by the snap-reading or ratio-delay technique. An investigation is described to collect more accurate data for the application of incentive plans, but the method could be useful for any studies requiring the assessment of downtime for research purposes.

Rational Decision-making and Economic Behavior.

THE COWLES COMMISSION FOR RESEARCH IN ECONOMICS (19th Annual Report, 1950-1951).

University of Chicago, 1952.

To be economical is to choose the best use of limited opportunities and resources. This applies equally to the business manager, the housewife, the hospital administrator and the army commander. To study how to choose the best decisions requires a study of rational behaviour, not actual behaviour. Yet study of actual behaviour is equally important, even if that behaviour is not rational ; first, because from a knowledge of actual decision-making one can learn how to behave rationally ; second, because the rational decision-maker has to take into account the possible irrationalities of his fellows ; a businessman's opportunities are limited by the irrational habits of his employees, competitors and clients as much as by the rational laws that underlie technology.

This is the theme of the 19th Annual Report of the Cowles Commission for Research in Economics, which describes the work done during the year under four groups, the relevant papers produced being listed under each group. These groups are : (i) single-person decision

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problems and multi-person decision problems, (ii) studies of actual behaviour, (iii) and (iv) statistical and mathematical tools useful in such problems.

These studies are mainly theoretical and are not taken to the point of actual decision-making in particular cases; they nonetheless provide useful references for operational research workers in this field.

A Study of the Lives of Pots used in Making Glass.

JOAN KEEN and DENYS J. PAGE (General Electric Co. Ltd.).

Applied Statistics, November, 1952; **1** (3), 163-168.

It was required to learn something of the factors that influence the life of clay pots used in making glass. It was not possible to undertake a planned experiment to provide data amenable to an analysis of variance; it was therefore necessary to devise a means of analysing the unbalanced data available from two years' actual working.

Inspection of the data indicated that seven variables should be considered. These were, the maker, furnace, gas, type of pot, position in furnace, type of glass, and clay mixture, and they each had between three and six levels, except for the glass melted, which had twenty levels. The system of analysis adopted was to select portions of the data for which balanced comparisons could be made; for example, pots made by Smith used under particular conditions of the other variables were compared with those pots made by Jones used under the same conditions. As the distribution of pot lives was found to be skew the median pot life was used in these comparisons.

Standardized pot lives were determined, using the ratios obtained in this way. More precise estimates of the ratios were then determined by a process of iteration. Hence factors were obtained for comparing individual pots or pot types, and the corrected lives were plotted on a control chart which enabled changes in the general level of performance to be determined.

Speeds and Normal Accelerations of Boeing "Clipper" Aircraft on North and South Atlantic Routes.

D. T. JONES (Ministry of Supply).

Aeronautical Research Council Reports and Memoranda. H.M.S.O., 1952. 4*s.* 14 *pp.*

Results obtained from *V-g* recorders fitted to Boeing "Clipper" aircraft on the North and South Atlantic routes between September, 1944, and May, 1946, are presented. The records cover about 3,300 flying hours and show that the maximum speed recorded is 215 m.p.h. (I.A.S.), and the maximum upward and downward accelerations are 2.3 *g* and 0 *g* respectively.

It is assumed that the frequency distribution of maximum speeds and accelerations obtained from a set of records of approximately equal flying times may be represented by a Pearson type III curve. Hence, from the actual results obtained, calculations are made of the maximum speeds and accelerations which are likely to be encountered in 10^5 flying hours.

A Quantitative Method for Determining Palatability of Pasture Plants.
DAVID REID (Grassland Research Station).
J. Br. Grassland Society, Dec., 1951 ; **6** (4), 187-195.

Methods used to date in the study of the relative palatability of herbage plants are reviewed. These have yielded qualitative data only and a new method is described for determining palatability on a quantitative basis.

A study of the relative palatability of fifteen strains of grasses is described, and the advantages and disadvantages of the method are indicated. The method involved the cutting and weighing of samples of the grasses, which were grown in plots arranged in a randomized complete block design, before and after periods of grazing. Analysis of the results revealed a very large sampling error, so methods of rank correlation were applied.

Human Relations in Industrial Operational Research.
A. W. SWAN (Courtaulds Ltd.).
The Engineer, 25th July, 1952 ; **194** (5035), 117-120.

The method of inauguration of an operational research department and its place in an organization are discussed. Relationships with higher management and with other departments are then considered, with a section on the planning of the work. Emphasis is placed on the service character of an operational research department and on the importance of individual and group discussions in carrying out its programme. The concluding section deals with human relations within an operational research department, with a discussion of differences in method and the factors which make for contented and enthusiastic work.

A Statistical Approach to some Basic Mine Valuation Problems on the Witwatersrand.
D. G. KRIGE.
J. Chem. Met. & Mining Soc., S. Africa, December, 1951 ; **52** (6), 119-139.

This paper describes the usefulness of scientific methods of mine valuation to improve the accuracy of estimation of the tonnage and grade of payable ore in a mine and so to enable the mining engineer to determine the correct policy of selected mining.

From an analysis of 28,000 inch-dwt. sample values it is shown that these values have a lognormal frequency distribution, and this distribution applies to any size of sampled area. It is shown how this enables a suitable size of sample to be decided so that a reliable mean value can be determined ; it also enables proper weight to be attached to the occasional very high value which is at present arbitrarily "cut" on the assumption that it is abnormal. Probability limits on the accuracy of the mean are determined for various sample sizes so that it is possible to say how high the sample mean must be before it can safely be decided that an ore block is payable, or how low it must be before the block can safely be abandoned as unpayable.

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The Mysterious Mission of O.R.O.
HERBERT YAHRAES.
Saturday Evening Post, 23rd Feb., 1952.

This article tells how the Operations Research Office came to be set up in 1951 and describes many of the operational military problems in the solution of which the civilian scientist can help. Some of these problems are strategic ; others are tactical investigations carried out in Korea. The qualifications of a successful operations analyst are considered and differences between his approach to a problem and that of a military commander are indicated.

BOOK REVIEWS

Three Studies in Management.
J. F. SCOTT and R. P. LYNTON.
Routledge & Kegan Paul. 1952. 18s.

In order to live at all, any organism, social or individual, must constantly adapt itself to change. The more rapid and extensive the changes forced upon it by external events, the greater the need for effective adaptive mechanisms to be developed. Owing to the war, to recent changes in social relations and to the pace of technological development, industry today is faced with this need as an urgent problem. As the authors of this book point out, "old skills need to be supplemented. There is room for new guides to the collection and assessment of facts and for more systematic study and communication of management skills. Implicit skills need to be made explicit ; much of what is taken for granted needs to be examined for it may no longer apply."

The stage is set neatly in an introduction and the main part of the book is divided into two. Part I is concerned with the empirical reporting of three case histories of organisations faced with adaptive problems, and Part II with the discussion and broad interpretation of the events recorded. The three cases concern firstly a colliery attempting to maintain flexibility of communication and control in the changing circumstances of the industry today, secondly the establishment of a hosiery finishing factory in an area where no traditional skills were available, and thirdly the problem of effecting change in a large, established, hosiery company.

The central problem comes out most sharply perhaps in the mining example. The operation of getting coal has certain inevitable functional characteristics which have produced a social structure and culture appropriate to them. Technological change is now taking place rapidly, but social and cultural changes are not keeping pace. A manager in these circumstances can only do his job adequately if he is aware of the social as well as the technical problems produced by the need to change. He must consequently recognise symptoms of human behaviour for what they are and what they represent, and be able to react rationally and with understanding.

The other two examples from the hosiery industry concern mainly

the problems of selection and training in situations where "born" or traditional skills have quickly to be supplemented.

The similarities and differences between the three cases are then discussed and certain general points brought out within a fairly broad conceptual frame of reference, with emphasis on the development of adaptive mechanisms. The basic problems encountered are so deep that the authors themselves could not claim to have gone more than just below the surface in the three cases examined, but nevertheless they have produced a readable, discerning and helpful volume.

The book concludes with Appendices concerned with Research Methods (which has some rather hard things to say about quantitative techniques) and a review of the growing body of reading concerned with the application of social science to industry. J.M.M.H.

Technological Applications of Statistics.
L. H. C. TIPPETT.
Williams & Norgate Ltd., 1952; 189 *pp.* 18*s.*

This book brings together a series of lectures given by the author at the Massachusetts Institute of Technology in 1948 to a mixed audience of industrialists, students and industrial statisticians.

It is in two parts, the first of which is on the subject of routine quality control. The usefulness of techniques used in quality control, however, extends far beyond routine inspection; operational research workers who may wish to apply these will find the basic methods described here in an elementary form.

The second part of the book deals with industrial applications of other statistical methods; there are chapters on the Theory of Error, Analysis of Variance and Correlation and Regression analysis. These are considered from the practical rather than theoretical point of view and are explained with a liberal quota of examples; the examples are taken mainly from the cotton industry and the steel industry, and many of them are of an operational rather than experimental nature. Operational research workers will find particular interest in the chapter on the practical application of the statistical theory of errors; here there is a discussion on the choice of significance level and choice of hypothesis and the important problem of assumptions regarding normality, equal variability, randomness and the inclusiveness of the estimate of error; all these are particularly pertinent to operational problems where it is so often difficult to be sure of the validity of one's data. The final chapter on planning an investigation also contains some useful thoughts on planning, especially economy in planning, as applicable to investigations as well as rigidly designed experiments. R.T.E.

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A SURVEY OF O.R. IN GREAT BRITAIN

by

CHARLES F. GOODEVE and G. R. RIDLEY

As a result of a number of requests for information, a survey has recently been carried out to discover to what extent operational research is now being used in Great Britain. The survey was based on questionnaire forms which were sent out to 210 organizations, including private firms, nationalized industries, civil service departments and all the research associations. Many types of organization have not been covered, notably those concerned with financial operations, e.g., banks, insurance, exporting, etc.

The organizations were selected, not with the idea of obtaining a representative sample of a "population," but rather to get as full a picture as possible without an excessive consumption of effort. Over two-thirds of the addressees were in large organizations or in those known to have active research departments. Care was taken to include those organizations where a member of the staff was a member of the Operational Research Club, and quite a number of organizations were selected from the subscription list to the Quarterly.

Each organization received a form on which it was asked for information about its operational research activities. Information was also asked on the way operational research, where existing, was organized, on the size of teams, on the chain of responsibility, etc. Together with this form was a covering letter in which operational research was defined as:

"*the application of the scientific method to provide executives with a quantitative basis for decisions regarding operations under their control.*"

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The letter continued:—

> " There are a number of variations on this, but you will note that the principal criterion is the use of the scientific method in fields other than those normal to a research laboratory which is concerned with equipment, processes, etc. Its usefulness is not confined to any one type of operation. It has been successfully applied (apart from its original military uses) not only to technical and administrative problems but also, for example, to organizational problems (such as flow of materials, transport and utilization of equipment), personnel problems (such as economics, accidents and labour turnover), or problems such as productivity or efficiency generally. Most operational research depends on observations of activities while they are going on."

The Extent of Operational Research

Replies were received from about 160 organizations. Some replied by filling in the questionnaire form, others preferred to answer in more general terms by letter, and some did both. Among those organizations carrying out operational research, the extent varied considerably; some were doing it all the time, while others only did it occasionally.

An attempt has been made to give a picture of the amount of operational research carried out by classifying the replies according to the manner in which they were put. The classification and the numbers in each group are as follows:—

1. We do not do any operational research. (31)
2. Some of the time most of us do it in a very broad sense (interpreted as using a quantitative basis for decisions but not necessarily as a research or by using the scientific method). (27)
3. We are active in routine fields such as quality control, time and motion studies, market surveys, etc. (interpreted as using techniques not so analytical as those in operational research). (17)
4. Although we have no operational research section, some of our sections perform operational research some of the time. (41)
5. We have at least one section (or individual) doing this sort of work, but they do not call themselves an operational research section. (27)
6. Yes, we carry out operational research and have an operational research section. (18)

It was of interest to find that most of the correspondents had a fairly clear idea of what was meant by operational research and that their interpretation of the term was close to that intended by the authors. In a few cases some judgement on the part of the authors was necessary in the allocation to groups, but it is considered unlikely that this materially affected the net result.

When it is remembered that the borders of operational research are extremely vague, the results of the survey can be considered satisfactory. Indeed, the exercise has helped to clarify the borders. For example, it has been found important to distinguish between a routine function such as the

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collection of statistics, the control of quality, rate fixing by time and motion studies, etc., and a research function such as in operational research. It is a job of research to develop the methods of a routine function and to study the operation or effectiveness of this function. (For example, one does research to develop new methods of chemical analysis, but the routine use of chemical analysis is not a research function.) Furthermore, a study of processes while they are going on should not be called operational research unless it is part of a wider study which includes the operators or the market, etc. Finally, an almost insurmountable difficulty has been in deciding whether methods used could be called "scientific" and, in classifying between groups 2 and 4 above, considerable subjective judgement was necessary.

The important part of the survey concerns groups 4, 5 and 6, and in this part the classification could often be confirmed by the examples given of work done. If groups 5 and 6 are taken together, it is seen that there are in Great Britain over 40 organizations having sections whose major activity may be classified as operational research, although rather less than half of them use that word in the name of their group. In addition to the above, the survey indicated that about the same number of organizations (group 4) carry out operational research in one or other of the parts of their organization at some time or other. These figures are somewhat of an underestimate in view of the limited circulation of the questionnaire. Where separate sections existed, they varied in size from one university graduate and an assistant to over 50 people. However, most of the sections consist of from 1 to 6 graduates with a similar number of others.

The person to whom the operational research section is responsible depends upon the organization in which the section lies. In research associations and research departments of large organizations, the sections are generally responsible to the director of research. In an industrial firm where the section is a separate unit and not part of a large research department, the responsibility is usually to someone of the general manager or director level. The sections in the civil service and nationalized industries are usually responsible, if not to a director of research, to the head of the particular division in which the research is carried out.

Types of Problems

In the questionnaire, the organizations were asked to give some examples of the operational research work which they had carried out. A classification of these is difficult, but they commonly fall under the following headings:—

To do with people alone.

(a) Organization and management.
(b) Absenteeism and labour relations.
(c) Economics.
(d) Decisions of individuals.
(e) Market research.

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TO DO WITH PEOPLE AND MACHINES.

(a) Efficiency and productivity.
(b) Organization of flow in factories.
(c) Methods of quality control, inspection and sampling.
(d) Accidents.
(e) Organization of technological change.

TO DO WITH MOVEMENT.

(a) Transport.
(b) Stocking, distribution and handling.
(c) Communications.

Of the 45 organizations that appear in groups 5 and 6, three are military departments (Navy, Army and Air Force), 11 are Government departments or large public utilities such as transport, electricity, etc., seven are research associations and the remainder are industrial firms of a variety of sizes (total employees from 40,000 to 25). Operational research was more commonly found in the larger companies, and many of the organizations in group 1 said that they were too small to have an operational research section.

Industries and organizations represented in groups 5 and 6 are: boot and shoe, broadcasting, building, chemical, coal, confectionery, engineering and machinery, industrial consultants, metal, pharmaceutical, social surveys, textile, transport (land, sea and air), and the defence services.

Similarly, group 4 includes: agriculture, baking, brewing, brick, civil and electrical engineering, department stores, fertilizer, hosiery, lamp manufacture, laundry, metal, petrol, photography, surveys of opinions and behaviour, textiles.

Companies already based on research, such as those in the chemical and electronic industries, commonly do not differentiate between operational and other types of research. The research departments of some of these have for long carried their scientific methods into wide studies of the operations of their companies.

Conclusions

While the survey did not specifically examine this point, the results indicate that a large part of the present activities outside the defence services have come into existence since the war. Obviously, also, there is a growing interest in the extension of the disciplines of the scientific method into problems of management.

The survey also shows the very wide range of activities and fields covered by the term " operational research." It illustrates the need for further effort to bring out the techniques used and types of phenomena found, to see how far they are common to different researches. The fact that the techniques used in one field have already been of great help to people working in other fields is, of course, the main justification for the development of one branch of science to bring such people together.

The authors are indebted to the many people who helped by supplying information for this survey and especially to those who generously gave very full details of their work.

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OPERATIONAL RESEARCH AND MATERIALS HANDLING

by

J. MURDOCH, B.Sc.*

MATERIALS handling is a very wide subject and covers a great diversity of equipment and methods. In this company it can be sub-divided into:—

1. Handling of raw materials, i.e., wagon tippers, rail distribution systems, mobile cranes, etc.
2. Transport of work in progress from operation to operation within a factory, i.e., cranes, " Lister " trucks, roller conveyors, etc.
3. Distribution and transport of finished products, i.e., efficiency and utilization of firm's vehicles, hired transport, etc.

Although the application of operational research in this field is still in its infancy, operational methods have been used in a wide range of problems from all of these three sub-divisions. The purpose of this paper is to describe the experience and benefits derived from use of these methods.

APPROACH TO PROBLEMS

It is found that all materials handling problems essentially boil down to determining a method of summarizing the system into a series of statistics or handling coefficients which will form a mathematical model of the system. The model varies from problem to problem, but it must satisfy the following conditions:—

1. It must represent the system with a known degree of error.
2. It should be capable of estimating and evaluating the effect of any possible change in handling practice.

This last condition is essential in any operational attack, so that not only is an objective solution obtained, but any other ideas or suggestions can also be evaluated against the analysis.

The operational approach will now be illustrated by considering the solution of an actual problem of metal handling in a foundry.

PROBLEM OF METAL HANDLING TO AND FROM CUPOLAS

Existing Handling System

Fig. 1 illustrates diagrammatically the layout of the foundry. Although there are three cupolas, normally only one is in operation at any time; two cupolas are employed together only when an exceptionally heavy tap is required for a large casting.

Consider the charging cycle first.

Charging Cycle. The metal skip (1-ton charges) on the charging bogie is filled by hand from an elevated platform. The full skip is then moved by bogie to the cupolas below the overhead skip hoist. The skip hoist drops the previous skip (empty) on to the bogie. The bogie operator transfers slings from empty skip to full skip and the full skip is then hoisted into the cupola while the bogie returns the empty skip to the platform where the charging cycle begins again.

* Mr. Murdoch is Operational Research Engineer at English Electric Co., Rugby.

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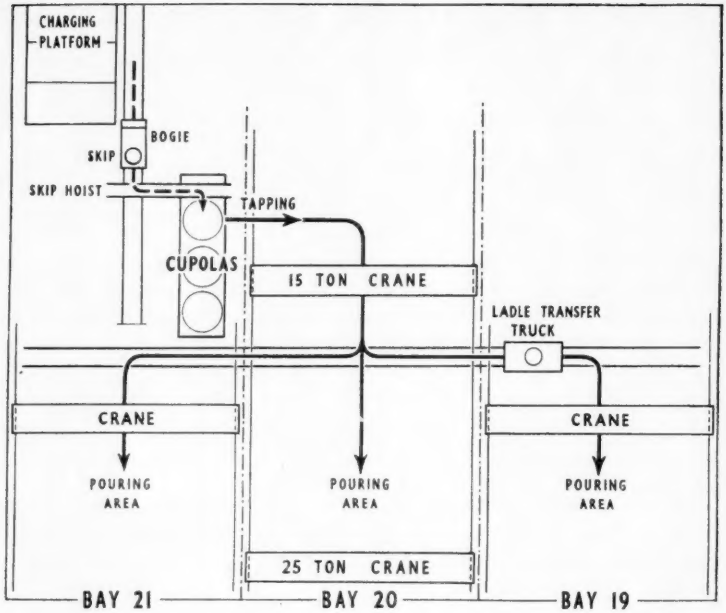

FIGURE 1 FOUNDRY LAYOUT

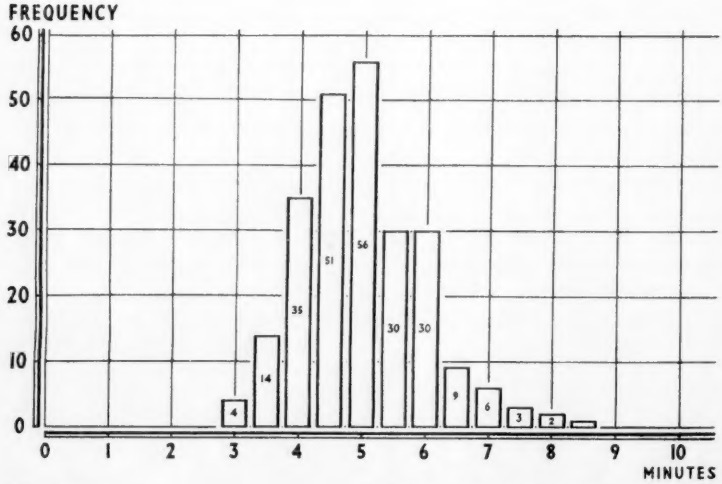

FIGURE 2 SKIP LOADING TIMES

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The bogie is electrically operated and runs on a rail track.

Four operators are involved in this cycle; two charging, one on the crane and one bogie operator.

Distribution Cycle. The empty metal ladle is picked up by a 15-ton distribution crane and held at the cupola pit while metal is tapped. The slag is then scraped off the metal. Two alternative moves are now possible.

1. If pouring is in the same bay (20) the distribution crane moves the ladle to the pouring position and holds it while pouring. The empty ladle is then returned by the crane to the cupola.

2. If pouring is outside the cupola bay, the crane deposits the ladle on the rail truck on the main gangway and returns to the cupola. The ladle is moved on the rail truck to the pouring bay, where it is picked up by an overhead crane. The empty ladle is returned in same manner and moved to the cupola by the 15-ton distribution crane when opportunity arises.

The Problem and Object of Analysis

The problem here was that although the cupolas are designed to melt at 10 tons per hour, the handling system was limiting the melting rate well below this design figure. The object of analysis was to design a handling system to enable the cupolas to melt 10 tons per hour.

The solution of this problem was essential in view of a decision to increase foundry output. In addition, there would be savings in labour due to reduced need for overtime, and in coke consumption due to melting metal at the optimum rate.

The operational research engineer must decide at this stage what statistics or handling coefficients are required for solution of the problem.

Referring to the charging cycle, the following coefficients are required:—

Skip loading	L mins.
Bogie movement time	M mins.
Skip transfer time	T mins.
Utilization of loaders	U_L
Utilization of bogie	U_B
Utilization of charging crane	U_C

For the distribution cycle, the following coefficients are required:—

Tapping rate	r_t cwt./min.
Pouring rate	r_c cwt./min.
Ladle movement times + slag removal time	t mins.
Utilization of 15-ton crane	U_{15}
Utilization of 25-ton crane	U_{15}
Proportion of metal poured inside cupola bay	p
Average weight of metal per ladle	w

These coefficients represent all factors which can have a bearing on the solution of the problem, and when combined they will form the necessary model of the system. It is at this stage that the operational approach is clearly seen. The problem has now been converted to its operational form.

The decision must now be made as to what data are required and in

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what form to yield these coefficients. It is obvious that these data can only come from a survey of the system under actual operating conditions. Three observers were placed on the shop floor, one each on the charging cycle, the 15-ton crane and the 25-ton crane.

Observer 1 recorded for each skip:—

Skip loading time (L): Bogie movement time (M): interval between
Skip transfer time (T): crane lifting full skip and placing it in cupola.

Observers 2 and 3 made a standard crane utilization study, recording:—

All work intervals of cranes: All delays and cause of delay and all movement times.

Charging Cycle Fig. 2 shows the distribution of skip loading times. The average loading time was 5 minutes, individual times varying from 3 minutes to 8.5 minutes.

The cycle breakdown is:—

Loading time	(L)	=	300 secs.
Movement to cupola	(M)	=	12 secs.
Changing skips	(T)	=	60 secs.
Movement to loading platform	(M)	=	12 secs.
Total cycle time (excluding delays)		=	384 secs.

Thus the attainable charging rate with 100 per cent. bogie utilization is only 9.4 tons per hour, so that:

$$\text{charging rate} = 9.4 \times U_B \text{ tons/hour}$$

where U_B is defined as

$$U_B = \frac{(L+2M \times T) \times \text{No. of skips}}{\text{Available time}}$$

The average time interval between lifting full skip and returning it empty by the skip hoist was only 2 minutes, illustrating clearly that limitation to increased charging rate is the utilization of the bogie.

Design of System to Charge at 10 tons per hour. To allow for variations in melting rate and delays, the system must be designed to achieve 10 tons per hour with a bogie utilization of less than 100 per cent. For example, to achieve this rate with present methods and a bogie utilization of 80 per cent., the average cycle time must be reduced to $\frac{60}{10} \times \frac{80}{100}$ or 4.8 minutes, i.e., a reduction of $1\frac{3}{4}$ minutes/cycle. It is immediately apparent that this reduction can only come from reduction in skip loading time, but the design and layout of plant prevented any addition to the number of loaders or to the loading area.

The decision made from analysis was to preload a tilting transfer skip on the platform. On the return of the empty skip the transfer skip would be tilted and metal shot into the empty skip on the bogie. This solution made the loading of skips continuous and independent of the bogie and modifies the system model to:

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$$\text{charging rate} = 12 \times U_L \text{ tons per hour}$$

assuming no change in average loading time or other coefficients.

Bogie utilization is now measured as:

$$U_B = \frac{2M + T \times \text{No. of skips}}{\text{Available time}}$$

since loading is independent of the bogie.

Thus the desired charging rate will be obtained with loader utilization of 80 per cent., the bogie and crane utilizations being below this figure.

Distribution Cycle. It can be shown that the distribution system can be represented by:

$$\text{Distribution Rate } D = \frac{3}{1/r_t + p/r_c + \frac{t}{w}} \times U_{15} \text{ tons per hour.}$$

This equation is the mathematical model of the system. The factors shown in the equation are the only factors affecting the distribution rate. From this equation the effect of any proposed alteration to the system can be accurately measured. Any alteration of method or practice which does not affect any of the coefficients will not alter the distribution rate.

The value of the handling coefficients is:

$r_t = 8.8$ cwts./min. $w = 29$ cwts.
$r_c = 4.4$ cwts./min. $U_{15} = 0.77$
$p = 0.43$

Design of System to Distribute at 10 *tons per hour.* Reference to the model shows that even under conditions of 100 per cent. crane utilization, the distribution rate will be only 9.6 tons per hour.

The coefficients r_t, r_c and w are based on foundry practice and cannot be altered, and little reduction in t is possible.

To achieve a distribution rate of 10 tons per hour, it was found that the best solution will be to reduce p to zero by installation of an additional crane in bay 20.

It is proposed that a 5-ton crane be installed at the south end of the bay to handle the layout of moulding boxes. The 15-ton crane will hold ladles during tapping and scraping off slag and will transport ladles to gangway. The 25-ton crane will pick up ladle, hold while pouring and return to main gangway.

These proposals give the following equation.

$$\text{Distribution Rate} = \frac{3}{1/r_t + \frac{t}{w}} \times U_{15} \text{ tons/hour.}$$

Substituting in this equation shows that the design will give a distribution rate of 13 tons/hour under conditions of 100 per cent. crane utilization. With present crane utilization, i.e., 77 per cent., a distribution rate of 10 tons per hour will be achieved.

ROAD RESEARCH

The following eight summaries refer to a selection of the work undertaken by the Road Research Laboratory during 1952. They are reproduced by courtesy of the Director, Road Research Laboratory, Harmondsworth, Middlesex, to whom anyone interested should refer for further information.

A Problem of Interference between Two Queues.

RN/1693/JCT.

The following theoretical problem is considered:—

A road has a section AB with traffic moving in a single lane only. Vehicles arrive at random from the two directions at rates q_1 and q_2 per unit time. Each vehicle in the q_1 stream takes a time α_1 to pass through AB, and will not follow closer than a time β_1 behind the vehicle in front of it. α_2 and β_2 are similarly defined. A vehicle will not enter AB if there is an opposing vehicle in it, but it will do so as soon as there is no such vehicle (and no vehicle in its own direction within β_1 or β_2 in front of it). It is required to find the mean delays w_1 and w_2 to vehicles in the two streams, when the process is in statistical equilibrium.

When $\alpha_1 > \beta_1$, $\alpha_2 > \beta_2$, equations are found for w_1 and w_2, but these are only solved if one of the β's, say β_2, is zero. The expressions for w_1 and w_2 in this case are rather awkward, though explicit, but they reduce to manageable proportions if, in addition, $\beta_1 = 0$ or $\alpha_2 = 0$, and some illustrative numerical results are given for these cases.

Applications of this analysis to other traffic problems are briefly discussed.

Some Factors Affecting the Accuracy of Manual Traffic Counting.

RN/1691/JCT. PCJ.

Some traffic counts were made simultaneously by nine observers to see how closely their results agreed. The various observers agreed to within $\pm$ 2 per cent. as to the total number of vehicles passing during the observations, and to within about $\pm$ 1 per cent. if a few gross errors are removed. The flow varied between 200 and 2,100 vehicles per hour, and averaged about 900 per hour. Approximate relations were found between the amount of traffic passing and the accuracy of the counting.

The enumerators included industrial staff and scientific staff, and there was a marked tendency for those with more scientific training to record more vehicles than those with less.

The errors were increased when the vehicles were classified into ten types, and bias, i.e., consistent under- or over-counting, was evident in counts carried out in relatively difficult conditions (1,000 vehicles per hour or more), but not in easier counts.

It is concluded that for short periods sufficiently accurate counting is possible up to quite high vehicle flows, but that enumerators are liable to give biased results for vehicle flows greater than 1,000 per hour. Whether this accuracy can be maintained over longer periods or when supervision is relaxed, is uncertain and requires further investigation.

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Pedestrian Subways.
RN/1713/MRJ. JAR.

Observations were made on the use of a pedestrian subway in central London. It was found that about 25 per cent. of elderly or infirm people used the subway, but only about 6 per cent. of the other people did so. The mean journey time measured through the subway was just under 50 seconds; over the road it was about 37 seconds. Traffic was delayed by the policeman giving passage to pedestrians crossing on top. The overall delay per vehicle was about 4.5 seconds.

There are about three accidents per year involving pedestrians near the subway. It is estimated that if all pedestrians crossed the road by the subway a sum of at least £1,800 per annum would be saved on the cost of accidents and the cost of having a policeman on duty there. The monetary saving in delay to vehicles cannot be estimated satisfactorily, but, assuming the cost per vehicle to be 5s. 0d. per hour, the cost of the delay is found to be about £2,000 per year.

A Substitute for Road Tests for Vehicle Headlamps.
RN/1648/GG.

A method of comparing vehicle headlamps is described in which the opinions of drivers were obtained under controlled conditions on a test track. Two cars, fitted with similar headlamps, were employed on a track about half a mile long, having a long straight section and two curves. Dummy men of dark material were placed at the sides and centre of the road. The cars started at the same time from opposite ends of the track and the drivers had the opportunity of assessing the merit of their passing beams both with and without glare from similar opposing headlamps. The method is intended to supplement the usual tests for determining the distances at which objects are recognized, and largely to replace road trials, where many conditions are uncontrolled.

A Method of Comparing the Performance of Vehicle Meeting Beams.
RN/1597/VJJ.

Seeing distances, in the light of vehicle headlamps, are found to depend very largely on the intensities of the beams of light which illuminate the objects and dazzle the drivers. The seeing distances have been obtained experimentally for a range of these intensities in a standard set-up. The data given in the paper may be used to calculate the seeing distances in the same set-up for any type of lamp, thus enabling the performance of the lamps to be compared without recourse to full-scale trials.

A Comparison of Four Vehicle Meeting Beams in Common Use.
RN/1598/VJJ.

A method of comparing the performance of meeting beams, by calculating the seeing distances they give in a standard situation for which the seeing distance with any meeting beam is close to the minimum, has been applied to four types of beam in use in different countries.

The method has been used to examine the effect of misaiming the four types of meeting beams, and also to estimate how seeing is affected in the case of unlike meeting beams.

The Effect on Accidents of Inadequate Vehicle Rear Lights.
RN/1604/GOJ.

Reasons are given for believing that about 1,500 casualties during the last three months of 1949 were directly due to vehicles having inadequate rear lights. This means that about 8 per cent. of all night casualties and 12 per cent. of non-pedestrian casualties at night might have been avoided if rear lights on vehicles had been better.

In order to arrive at this estimate three types of accident have been investigated: (a) parked vehicles hit in the rear, (b) temporarily held-up vehicles hit in the rear, and (c) front/rear collisions between two vehicles moving in the same direction on the same road. It was found that the ratio of night/day casualties from these types of accidents was in some cases, especially in non-built-up areas, significantly greater than the ratio of night/day casualties for all types of accident.

Goods vehicles and pedal cycles were the most liable to be hit in the rear at night and cars and motor cycles were most frequently the hitting vehicles. By comparison with daytime accidents, post-war cars, with their improved rear lights, were much less likely than pre-war cars to be hit in the rear at night.

Indications are given that the lights on goods vehicles and pedal cycles were especially inadequate.

(*A Bill has recently been introduced in Parliament making higher standards of rear lighting a legal requirement.*—ED.)

A Method of Presenting the Reflection Characteristics of a Road Surface for Use in Street-Lighting Investigations.
RN/1651/AWC.

The reflection characteristics of a surface are extremely complicated, being a function of three angular variables. It is shown that for the particular case of street lighting only certain ranges of angles are encountered, and that information regarding these ranges suffices for the purpose of evaluating the brightnesses of road surfaces. This enables a simplified treatment of the reflection properties to be given.

The report of the Advisory Council of the Department of Scientific and Industrial Research for 1951–52 includes a section on operational research, the wider application of which in research associations is welcomed, although it is pointed out that this type of work is by no means new or unusual in industry. One of the great advantages of O.R. is stated to be that it enables better use to be made of existing machinery and labour, often without substantial capital outlay. Reference is made to projects being undertaken by the Wool Industries R.A., the Cast Iron R.A., the Boot and Shoe R.A., and the Iron and Steel R.A.

In a leading article reviewing the Report, *Engineering* remarks (10th April, 1953, **175** (4550), 466) that operational research is perhaps 20 or 30 years' old. "Research associations may by their example influence trade associations towards realizing that something is to be gained by analysing their own activities with scientific dispassion, and if such example is more likely to be followed when the activity is called 'operational research' the term is to be welcomed."

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ABSTRACTS

The Optimum Distribution of Effort.
BERNARD O. KOOPMAN (Columbia U.).
J. Operat. Res. Soc. America., February, 1953 ; **1** (2), 52-63.

A theoretical mathematical statement of this type of problem is presented, but not applied to any specific example.

The Monte Carlo Method as a Natural Mode of Expression in Operations Research.
GILBERT W. KING (International Telemeter Corporation).
J Operat. Res. Soc. America, February, 1953 ; **1** (2), 46-51.

The Monte Carlo method is explained and its advantages are indicated in obtaining quick and accurate, though not precise, results in problems where more refined methods are intractable.

The Effect of Promotional Effort on Sales.
JOHN F. MAGEE (Arthur D. Little Inc.).
J. Operat. Res. Soc. America, February, 1953 ; **1** (2), 64-74.

A disguised case study of the effect of promotional effort on sales of coffee to dealers is described in theoretical terms based on existing sales data. Measures were found of the relative efficiency in terms of gain in sales of various distributions of promotional effort and of the effect of promotion on individual accounts, and a broad view of the whole operation was presented.

The Reliability of Airborne Radar Equipment.
DAVID M. BOODMAN (O.E.G.).
J. Operat. Res. Soc. America, February, 1953 ; **1** (2), 39-46.

The distribution of operating lives to failure of various individual components (such as vacuum tubes) is examined and the probable expectation of trouble-free working is determined for a complete set containing large numbers of components, each of which is vital to its operation. It is shown, for example, that a set having 250 vacuum tubes and 2,500 other parts has a 50 per cent. chance of surviving two hours. It is concluded that there is a practical limit to the complexities of such equipment.

Operations Research in Agriculture.
C. W. THORNTHWAITE (Seabrook Farms Inc.).
J. Operat. Res. Soc. America, February, 1953 ; **1** (2), 33-38.

Growth rates of peas were studied for all months of the growing season and for different varieties of peas. From this information, a planting programme was devised which would ensure that different fields would mature in succession at a daily rate which was within the capacity of the harvesting and processing departments, so that the whole crop could be harvested in prime condition.

Similar studies enabled the system to be extended to other crops such as corn, beans and spinach.

Using Science to Reach Decisions. Operational Research as an aid to Management.

C. F. GOODEVE (B.I.S.R.A.).

The Manager, May, 1953; 257–260.

Some examples of operational research in the iron and steel industry are described in general terms to illustrate the types of problem which may be tackled. Thus problems which involve striking the right balance in the consumption of various resources are illustrated by reference to Passano's work on rod lengths (*Operat. Res. Quart.* **1** (2), 28) and, on a bigger scale, B.I.S.R.A.'s investigation into the handling of imported ore.

The value of productivity studies in analysing consumption rates is discussed. Other examples referred to concern the investigation of defects and the development of a new approach to the analysis of works accidents.

Statistical Methods and Operational Research in Transport.

F. A. A. MENZLER (London Transport).

Journ. Inst. Transport, January, 1953; **25** (2), 2–12.

This paper sets out to describe how answers to certain types of transport problems have been, and could only have been obtained by the use of scientific methods.

After some discussion of the nature of O.R. some problems of sampling and the interpretation of statistics are illustrated by reference to figures for timing chain failures, punctures, and fuel-injection pump failures. Some examples of specifically O.R. projects are then described in general terms; many of these involved studies of passenger habits in such matters as the relation between accidents and boarding and alighting from buses or the use of stanchions; in studies to determine the value of destination indicators, the collection of data by direct observation was impossible and polling techniques had to be used.

An investigation into the effect of different driving techniques on fuel consumption is more fully described and finally brief reference is made to the organization of O.R. in London Transport.

New Techniques in Management Planning and Control.

MAR W. GRESAP, JNR. (Westinghouse Electric Corp.).

Paper read at the Society for Advancement of Management Meeting, 30th Oct., 1952.

Planning is defined as the formation of plans by an orderly process to determine the future development of the business. Democratic business planning, as opposed to rigid arbitrary planning, must provide a goal, the stimulus necessary to achieve the goal, and the required teamwork.

There are four steps in long-term planning: determination of the objectives, the policy, and a programme to achieve the objectives; finally the setting up of controls for systematic review.

Techniques of planning are considered, including the analysis of trends and cyclical effects to determine the best development and provision for idle capacity.

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HISTORICAL WRITING

Some Problems of Material Selection.

by
MARGARET GOWING

IN 1942 the War Cabinet decided that the social, economic and administrative experience of the war should be submitted to scientific study. A team of independent and professional historians and economists under Professor (now Sir KEITH) HANCOCK, undertook the task and all of them were given free access to official documents. Access by independent historians to such documents so soon after their creation was unprecedented and was an inestimable advantage. But it also posed serious problems of method. For the bulk of the papers was immense; for example, one single department—the Board of Trade—accumulated over the war years 12,000,000 files occupying 16 miles of shelving. The war historians have evidently mastered this problem of bulk for 11 volumes have already been published and the rest of the programme is well on the way to completion. The editors of this journal thought that a brief account of the methods used might well be interesting to people concerned with operational research.

First, I should perhaps say that the task of the historians was possible only because they were members of a team; the problems of manpower, shipping, inland transport, financial policy, and rationing were all closely interwoven, yet no single person could have tackled them all. So the subjects were divided out amongst historians; the historians of food policy, raw materials control and shipping, or of war production, civil industry and manpower could thus exchange the fruits of their research. Teamwork is a commonplace of research in the physical sciences, but its systematic use for historical research is something new and something destined to grow.

The war historians enjoyed another general advantage. Nearly all of them took up their posts while the war was still on; as they were working in the departments whose work they were describing, they saw policy being formulated and executed and could draw on their own memories when they came to write. Also, of course, most of the main actors in the events that the historians were discussing were still alive and could, when their memories were strong enough, answer questions and supply helpful comments on drafts.

In spite of all this, however, the main task for each historian was to sift, and make sense of, the formidable mountain of documents. I myself have worked on two of the volumes in the civil histories series and the latest of these, **Civil Industry and Trade,*** was based on those 12,000,000 files that formed the war-time record of the Board of Trade. My fellow author and I could identify without much trouble the main problems to be dealt with partly because most of the problems were those that were to be expected from a broad analysis of the war economy and partly because we had lived in the Board of Trade and seen at close hand developments

* E. L. HARGREAVES *and* M. M. GOWING, *London*, 1952; *Her Majesty's Stationery Office*; 678 *pp.*; *price* 37s. 6d.

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in, for example, price control, rationing and utility production. We also simplified our task by acquiring copies of any regular departmental notes, reports and instructions and of the papers of departmental committees.

When beginning detailed research on a particular policy, we tried first to get hold of the main policy files on the subject. This was by no means as easy as it sounds. With the war-time multiplication and pressure of Government business and the employment of inexperienced staff, standards of filing fell sharply. The names of files often bore little relation to their contents, and many important papers were not filed but were kept in private drawers. After examining the registry's list of files on a particular subject, we had therefore to do a good deal of detective work in order to assemble the files and papers from which the story of the development of a policy could be pieced together. Usually persistence was rewarded, at the cost of looking through a multitude of useless files. But occasionally gaps remained. These could be filled sometimes by private reminiscences and sometimes, if memories failed, by authors' hunch allied with deductions from available statistics.

For example, we were anxious to explain the reasons for the two sharp drops in the clothes ration just before and just after the end of the war. The Board of Trade had never intended the ration to drop like this, and it seemed to us possible that what had happened was that the "clothing budget" which governed output had been consistently "underplanned." For a time, the gap between demand and supply had been cushioned by stocks at all the various stages of production and distribution; when these cushions were deflated there was trouble. If this were true, it was an important lesson that might well be useful to learn should the need for clothing rations and budgets ever recur. The key files on the subject seemed, however, to have vanished or never to have existed, and the memories of officials on the subject were hazy and conflicting. We therefore worked on our "hunch" and examined all the figures for production of cloth and clothing, for deliveries of cloth to manufacturers, and for stocks of cloth and clothing at all stages of processing and distribution. We found from these that our hunch was right and that our conclusions were justified.

It would thus be fair to conclude that the method of the historians has been a combination of hunch, detection work and methodical statistical analysis.

Operations Research Society of America.

The O.R.S.A. will now accept applications for membership from overseas. The annual subscription is $10.00 ($3.00 for students). Further particulars can be had from John B. Lathrop, secretary, 30 Memorial Drive, Cambridge 42, Mass., U.S.A.

In future the regular announcement on our inside back cover of the contents of the current Journal of the O.R.S.A. will be amplified by short descriptions of the articles. Abstracts will not, therefore, be included in our abstracts section.

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OPERATIONAL RESEARCH QUARTERLY

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EDITORIAL NOTES

APPLICATION OF O.R.

OUR LAST issue contained an account of a survey of operational research in Great Britain by Sir CHARLES GOODEVE and G. R. RIDLEY. In that survey it was found that, out of 45 organizations which were clearly carrying out O.R., 21 were military or other Government departments, public utilities or co-operative research associations. In other words a substantial proportion of the total effort given to O.R. is in organizations which are not directly responsible for production. In such cases a particular problem arises in ensuring that the research is conducted in such a way that the appropriate executive gives due attention to it in reaching his decisions.

An example is the work of the Road Research Laboratory. We have in recent issues devoted considerable space to O.R. in connexion with roads. The development of an adequate road system in this country is among the biggest and most urgent problems, and it is one which cannot be satisfactorily settled without extensive O.R. The Road Research Laboratory is doing first class work but its resources are limited. If it were asked to help in a fraction of the problems in which it could help, it would be swamped. Are we to conclude that the road authorities are acting without applying O.R. and without even paying attention to the results of O.R. which has already been carried out?

The development of roads is under the control of numerous separate authorities. The Ministry of Transport is responsible for a few of the major trunk roads, but most roads are controlled by the

county surveyors' and planning departments, who carry out this major task with the Ministries of Transport and of Local Government and Planning holding a watching brief.

Ideally, each county surveyor and planning department should have a trained O.R. staff. It is doubtful, however, whether any has. For the most part, their staffs are made up of surveyors and engineers. It would not be unfair to say that such staff, while no doubt excellent at building roads, are quite unsuitable for the more important task of deciding what roads should be built. They are unsuitable for two reasons; firstly because they would be biased—what engineer could resist the temptation to build vast new roads with fine sweeping curves if he had half a chance? Secondly because they are not trained to collect and analyse the type of data required.

This problem is urgent. At the present time each county is putting forward its development plan which is supposed to fix what major road building will be undertaken during the next 20 years. To take a simple example, the East Sussex plan, which has recently been published, proposes the building of a new double track highway across most of the county between East Grinstead and Eastbourne. Everybody using the road knows that on a few peak holiday weekends there is serious congestion on this road with holiday-makers returning to London. For the rest of the year, however, the present road is more than adequate for its traffic. Before this scheme was put forward did anybody evaluate the potential saving in holiday-makers' time and compare it with the real cost of the road? And how does the net value (if any) so found compare with the net value of other possible, and seemingly much more urgent schemes in other parts of the country?

This example underlines the importance, so rightly stressed in early definitions of O.R., of linking the research to the job. Only by the development of O.R. teams in each county can the work of the central laboratory become fully effective.

Operational Research Club

"Assessing Priorities for Technical Effort" will be the title of the paper for discussion at the first meeting of the coming session, on 10 November. It will be presented by G. H. L. Andrew (British Nylon Spinners, Ltd.)

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DISCHARGING IRON ORE

by

R. T. EDDISON* and D. G. OWEN*

THIS PAPER attempts to review the operation of importing iron ore, from overseas dock-side to home dock-side, in order to determine how it can best be organized to keep costs as low as possible. The work described formed part of an investigation of the whole process of importing ore right up to the blast furnace bunkers. It is centred round a study of the costs of construction and operation of ore-ships and discharging equipment. This paper is confined to

(a) Explaining the objectives of the research.
(b) Describing the main problems considered.
(c) Summarizing the general conclusions.

GENERAL DESCRIPTION OF THE OPERATION

A central organization, B.I.S.C. (Ore) Ltd., buys iron ore abroad for the whole industry, and arranges for its transport to British ports. Most of the ore is brought in ships chartered for single journeys or for periods of time. Charges for loading and unloading are covered, together with the shipping charges, by charter rates agreed with the ship operators. Further handling necessary to bring the ore from the quays to the blast furnace bunkers is paid for by the consumer and is not considered in this report.

Charter rates are subject to very wide and sudden fluctuations. For example the average rate in 1950 was 22s. 4d. per ton and the average during the first six months of 1952 was 46s.; by the end of 1952, however, rates had fallen almost to the 1950 level. This introduces an element of great uncertainty into the economic assessment of the problem.

The low rates in 1952 were associated with some laying up of ships, as in 1950, so they may be insufficient to allow a full return on capital after covering operating costs; they have therefore been regarded as minimum rates (at current costs) rather than average rates which could be maintained over a long period.

The unloading process, paid for in the first instance by the ship operator, is at some ports under steelworks control, this is not so at general ports, although in many of the latter the ore traffic is kept almost entirely separate from the port's other activities. Imports were under ten million tons in 1951 and it is estimated that some sixteen million tons per year will be required by 1957; a greater proportion than at present will be received at wharves controlled by units of the iron and steel industry.

*British Iron and Steel Research Association.

There are three main types of unloading machine in existence: the slewing crane, the "Kangaroo" crane, and the man-trolley unloader. So far, jib-cranes lifting more than 10 tons including the grab have not been used, but unloaders up to 25 tons have been built. On average, with all types of equipment, about 90% of the ore in a ship is at present unloaded by grabbing with little or no need for manual labour. The remainder, a proportion which varies greatly from ship to ship, has to be shovelled either into positions where the grabs can pick it up—this is termed "trimming"—or into tubs which the crane can lift out of the hold. "Tubbing" is normally confined to operations with small cranes which are unable to perform the manoeuvres with the grab which are required when trimming.

The necessity of having a large force of stevedores for the later stage of discharge means that the utilization of this labour, already intermittent due to irregular arrivals of ships, can become extremely variable. Stevedores are employed by the National Dock Labour Board and are available to employers as required. Usually crane and unloader drivers are regular employees of the port or wharf.

Objective

The first step in the enquiry is to decide exactly what its objective is. A number of possible objectives could be set, depending on the position of the interested party. For example, for those concerned with the logistics of importing ore the most pressing need might appear to be to arrange for the ports to handle the increased tonnages expected; those concerned with shipping might regard a reduction in ships' turn-round time as an end in itself; similarly operators of the port unloading equipment might limit their objective to a reduction of their own costs.

All these individual objectives, however, are of concern to the iron and steel industry as a whole as it must ultimately pay the full cost of all the operations involved in the importation of the ore. The primary objective of this enquiry is, therefore, to discover what should be done to lower the *total* cost of transporting ore from overseas port to unloading wharf, and to balance the savings and losses all along the line. (The subsequent handling of ore after unloading will be ignored here; the optimum arrangements for shipping and unloading will not be greatly affected by the means of further transport from quay to furnace.) It is convenient to divide the total cost into two parts:—

(*i*) *Shipping Cost:* the cost of the sea journey, plus the value of time spent in the loading port.
(This is not affected by conditions at the British port).

(*ii*) *Total Cost of Discharge:* the cost of operating unloading

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installation, plus the value of the time ships spend in the unloading port.

(This is under the direct control of the British port, but it also depends on the type and size of ship.)

The essence of the problem is that these operations can be varied: one can use faster or slower ships, bigger or smaller unloaders. It is necessary, therefore, to consider what features are controllable and how they affect each other and the total cost.

Factors Affecting the Total Cost

The many factors affecting the cost of the operation are brought together in Figure 1; the items shown in boxes are the factors which are at least to a limited extent controllable, although they cannot all be varied independently of each other in practice. Oval frames are used for aspects of the situation in unloading ports which vary as a result of choosing different values of the controllable factors.

Whenever two items are joined by an arrow this implies that variation of the one causes, or must be accompanied by, variation in the other, provided that other conditions remain unaltered. The factors which determine unloading cost and turn-round-time are shown in detail. Only the more important of those which affect cost of the sea journey and in the loading port are indicated.

Our object is to devise a means of observing the simultaneous effects of as many as possible of the controllable factors on the cost of the operation. To do this, they must be expressed quantitatively.

Sources of Data

The analysis of the factors discussed in the previous section falls conveniently into four groups. First there are the effects of unloading installation, type of ore, and ship design on rates of discharge; second there is the prediction of congestion delays and turn-round-times for various values of service time and berth occupancy; thirdly there is the costing of the unloading and ships time; and fourthly there is the determination of shipping cost at sea depending on the type of ship used.

Data for the first group were obtained principally from records of discharging cargoes in the past, supplemented by detailed observations on a few cargoes while actually being discharged. The past records analysed covered a period of $1\frac{1}{2}$ years and included nearly 3,000 cargoes. Discharge took place at some 12 major ports and there were about 40 different ores and nearly 900 different ships

represented. Furthermore, those ships which made several separate voyages tended to carry the same ore each time and to appear at only a limited number of ports. The 3,000 voyages did not, therefore, comprise a large sample and the data were not in a convenient form for standard methods of statistical analysis. *Ad hoc* methods of analysis had to be developed and although these did not enable

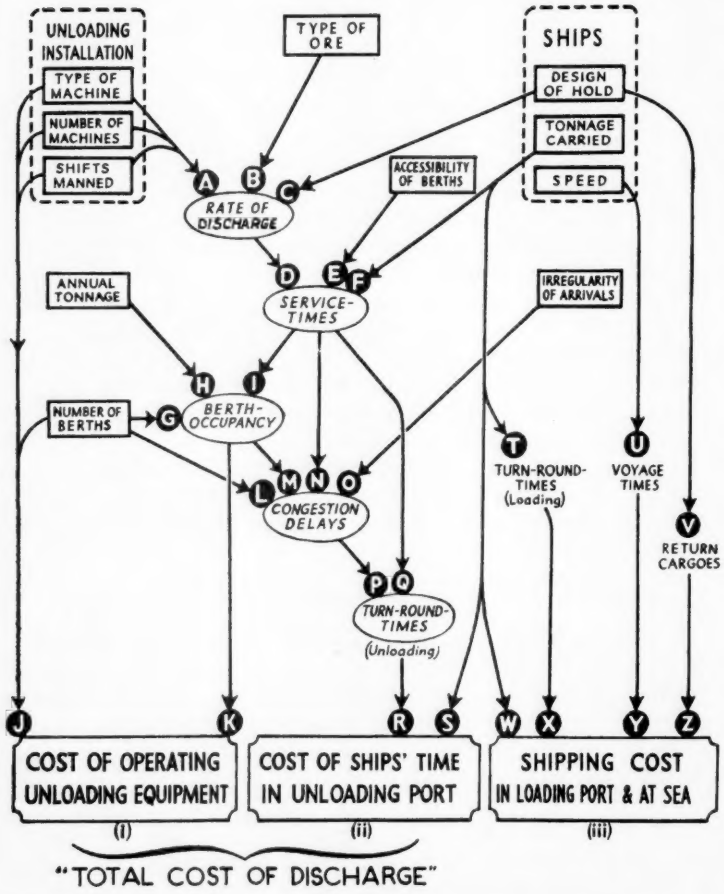

FIGURE 1. Relations between the factors affecting the cost of shipping and discharge. *See opposite page for key.*

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KEY TO FIGURE 1

(i) Cost of Operating Unloading Equipment

Rate of Discharge depends on (A) features of the installation,
(B) type of ore,
and (C) design of the ships' holds.

Service-Times depend on (D) rate of discharge,
(E) accessibility of the berth (i.e., time taken to approach and leave berth),
and (F) tonnage carried by the ship.

Berth-Occupancy depends on (G) number of berths at the port,
(H) annual tonnage handled,
and (I) service-time.

The Cost of Operating the Unloading Equipment depends on (J) the installation,
and (K) the use made of it, berth-occupancy.

(ii) Cost of Ships' Time in Unloading Port

Congestion Delays depend on (L) number of berths,
(M) berth-occupancy,
(N) mean service-time,
and (O) irregularity of ship-arrivals.

Turn-Round-Times are the sum of (P) delays,
and (Q) service-times.

The Cost of Ships' Time in the Unloading Port depends on (R) turn-round-time,
and (S) size of ship.

(The sum of (i) and (ii) above is the *total cost of discharge*)

(iii) Shipping Cost (in Loading Port and at Sea)

In comparisons of different types of ship on some particular voyage:

Turn-Round-Time depends on (T) the tonnage loaded.

Voyage Time depends on (U) speed of ship.

Return Cargoes the possibility of using ships for this purpose depends on (V) design of hold.

Shipping Cost (loading & at sea) depends on (W) size of ship,
(X) turn-round-time (loading),
(Y) voyage-time,
and (Z) whether a return cargo is carried.

precise estimates of error to be made, some useful quantitative conclusions could be drawn. For example it was found that the easiest ores could be discharged approximately twice as fast as the most difficult from the same ship and using the same unloading installation; and the best ships then in use could be discharged about 50% faster than the average. It was indeed possible to go further and associate certain ship design features, such as size of hatch in relation to area of hold, with the discharge rates that could be achieved. It was therefore possible to estimate the unloading rates that could be expected if ore-carriers were built and brought into service, i.e., ships specially designed for the carriage and rapid discharge of iron ore and consequently unsuitable for most alternative cargoes.

With unloading installations it was necessary to know not merely what rates of discharge they were achieving but what they could reasonably be expected to achieve, after modifying the organization of their operation in any way that might prove desirable. For this purpose observations were made of the detailed operations of the equipments, the whole unloading operation being broken down into its component parts. In this way it was also possible to make reasonable assessments of the unloading rates which could be expected from a number of types of installation not then in use for ore-discharge.

Data for the prediction of congestion delays were also obtained from the records of past arrivals. (Congestion delays are delays to ships after they have entered the port, which arise because the ships have to wait for berths to be vacated by other ships.) Although the arrival of ships is under some degree of control since the movement of ore is an ordered process, it was found nevertheless that, when seasonal fluctuations in the trade were taken into account, the distribution of arrivals of ships in British ports was effectively "random". It was therefore possible to develop the theory of queueing to enable the average congestion delay per ship to be predicted for each port from a knowledge of the number of berths, the service-time and the berth-occupancy. The berth-occupancy is defined as the proportion of time that a berth is actually occupied by a ship being discharged; it is therefore calculated directly from the annual tonnage and the mean service-time, the latter being determined by the size of ship and the capacity of the unloading installation.

This theory was applied to predict delays over the period for which data were available and the delays so predicted were compared with the delays actually experienced. A satisfactory agreement was found so that it is possible to use the theory to predict future delays which are to be expected for any required value of annual tonnage and for various types of ship and port installation.

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Costs of operating a number of port installations were obtained. These were broken down into their component parts, and from these comparative costs were built up for any required type of equipment and for any manning scale that needed to be considered. The items of cost included were labour, electric power, maintenance, depreciation and interest on capital (including berth structure). These costs can be sub-divided into tonnage costs (i.e., those which are directly proportional to tonnage) and time costs (i.e., those which are proportional to time irrespective of the tonnage handled). The cost per ton of ore can thus be calculated for any desired value of the berth-occupancy, equivalent to a particular annual tonnage per berth for any given installation. It appears that there is no great difference in operating cost per ton of ore between the machines considered, providing the berth occupancy is the same in each case. In determining the most economic rate of discharge, therefore, a "standard" unloading cost, depending only on berth-occupancy, can be used.

Costs of operating ships were derived from actual construction costs and operating costs. Three sizes of ship were considered: 8,000 tons, 14,000 tons, and 20,000 tons, as it was found that the ports fall into three groups which could accept ships of these sizes. For each size of ship two figures were obtained: cost per ton per day at sea and cost per ton per day in port (where fuel consumption is greatly reduced). For chartered vessels, especially those chartered by the voyage, the charter rate is, of course, determined more by the play of the market than by actual operating costs. This point will not be considered further in this paper.

Discussion of Results

As a result of the analysis made of the factors affecting total cost it is possible to make predictions about the effects of changing the variable factors. For example, it is possible to say what will happen to ship turn-round times if rates of discharge are varied by installing different types of unloading equipment. Furthermore, from the assessment that has been made of the costs of installing and operating the different types of unloading equipment and of operating different types of ships, it is possible to determine the effect on shipping cost in various circumstances of expenditure on various forms of unloading equipment.

As has been stated, it is found that there is no great difference in operating cost between most of the unloading machines considered, providing the berth-occupancy is the same in each case. The cost of operating the unloading equipment can therefore be related to berth-occupancy; in general this cost will be on a curve which

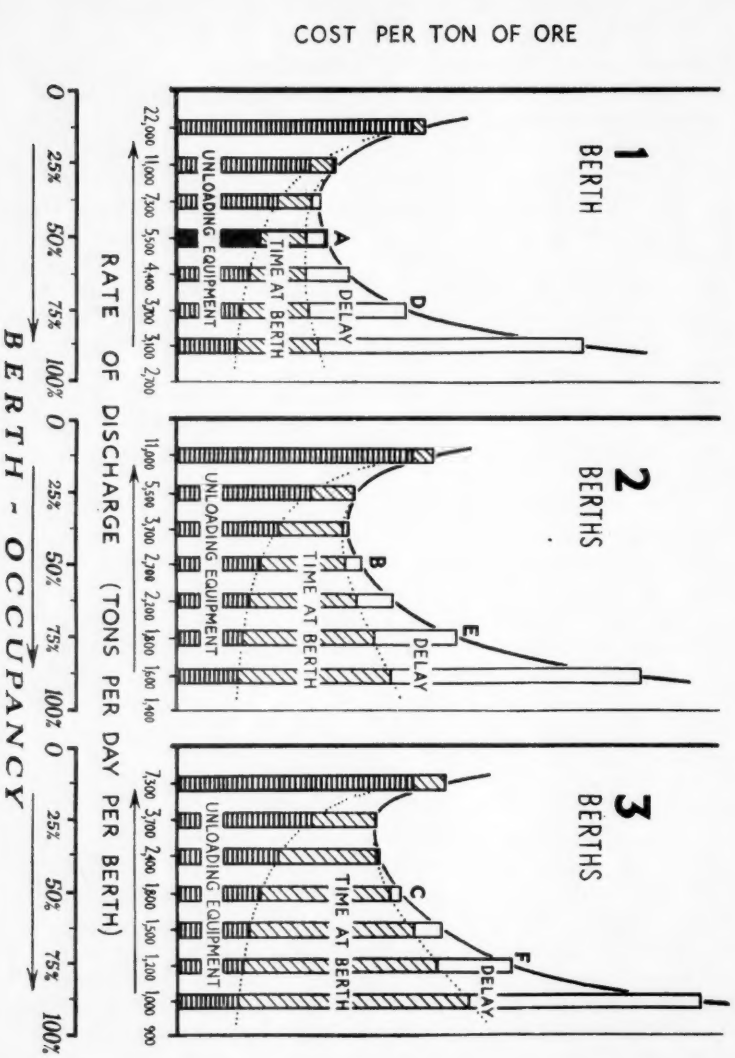

FIGURE 2. Total costs of discharge for a port unloading 1 million tons of ore per year from 8,000-ton tramp vessels.

falls as berth-occupancy increases (i.e., as the equipment is more fully utilized). The cost of ship's time in port on the other hand will rise because of increasing delays as berth-occupancy goes up; this rise becomes very steep as berth-occupancy approaches unity.

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These two costs can be added together to find the total cost of discharge, and Figure 2 indicates the kind of result that is obtained. Here the costs of various ways of unloading 1 million tons of ore per year from tramp vessels carrying an average of 8,000 tons each, are considered as an example, in order to illustrate the principles which must be followed to obtain the lowest total cost of discharge.

In these diagrams, each vertical bar represents the total cost per ton which results from providing equipment on each berth capable of the rate of discharge indicated on the horizontal scale. The berth-occupancy when handling 1 million tons per year is shown on the lower scale. The heavily-shaded portion of the cost is the operating cost of the unloading installation: the remainder is the value of the ships' time in port, made up of time at berth (shaded) and delays (white).

The lowest total cost of discharge is obtainable only with a single berth equipped to give a rate of discharge approaching 7,000 tons per day. Actually 5,500 tons per day gives a cost very close to the minimum—see "A" in Figure 2; equipment faster than this lowers the cost by very little at the price of considerable inconvenience from having a lower berth-occupancy and higher peak-loads to deal with.

To provide equipment of the same total capacity, but to spread it over two (or three) berths, adds to the total cost—see "B" (or "C") in Figure 2—since it keeps each ship at the berth two (or three) times as long. And a multi-berth installation with a smaller total capacity (e.g., "E" or "F") gives a very much higher cost because turn-round-times are much longer.

The optimum (i.e., the lowest cost) installation for the tonnage in question, therefore provides for rates of discharge between 5,500–7,000 tons per day at one berth and this involves a berth-occupancy of about 50%. And the general principle is that the lowest possible total cost of discharge requires the provision of sufficiently fast equipment on a single berth. Conversely, the highest cost results from having several berths inadequately equipped or manned.

The optimum rate of discharge becomes very high when a large tonnage is to be handled, so that even the fastest available machines on one berth, manned continuously, may not be adequate to produce a cost near the minimum, in that case a two-berth installation gives the lowest cost achievable in practice. Similarly, at a still greater tonnage, three berths become preferable. At multi-berth installations every berth should be equipped to the same standard.

Additional berths can, therefore, be economically justified only when the tonnage to be handled is so great that the optimum rates of discharge without them is unattainable. Evidently this does not

occur unless considerably more than 1 million tons per year are to be handled, provided that continuous manning is practicable. But there are many ports in operation where machines of only moderate capacity are installed on several berths. British ore-handling ports have generally, in fact, been equipped in the manner of "D" or "E" or "F" in Figure 2 with a high total cost of discharge in consequence.

It may be observed that the optimum rate of discharge for any tonnage will be virtually unchanged if the danger of congestion delays to ships proves to be less than has been assumed. Even with perfectly scheduled arrivals and no delays at all, Figure 2 shows that a single berth would still be preferable, and installation "A" would still give a cost (unloading plus time at berth) indistinguishable from the minimum.

Unloading Equipment for U.K. Ports

By the method described in the previous section, the most economical capacity to provide for every tonnage has been determined approximately, and this is shown for discharging tramp vessels in Figure 3. There is often more than one type of equipment which will give the required rate of discharge, and the installations which are indicated are intended only as examples.

Adequate rates of discharge for tonnages over about $\frac{1}{2}$ million tons per year are impracticable unless the equipment is manned continuously while a ship is in port, including nights and weekends. If this is not done, the total cost will be appreciably higher, as can be seen from Figure 2.

From Figure 3 it is apparent that tonnages less than about $\frac{1}{4}$ million tons per year can only be handled at comparatively high cost. A quarter of a million tons per year cost more than 50% more per ton to discharge than 1 million tons when the ships' time is taken into account. It is, therefore, desirable that ports should not handle small tonnages if it can be avoided without incurring unduly great land transport charges. Above 1 million tons per year no great gain occurs by increasing the intake, although the fact that port administration expenses have not been included means that in practice the cost may fall a little more than is shown.

The quantity of ore which justifies a two-berth port instead of a single-berth port has been shown to depend on the maximum rate of discharge that can be achieved at a single berth. In Figure 2 it is assumed that two 25-ton unloaders give the fastest discharge practicable with tramp vessels. At tonnages approaching $1\frac{1}{2}$ million tons per year such an installation becomes less and less adequate and between $1\frac{1}{2}$ and $1\frac{3}{4}$ million tons per year it becomes more economic to have two berths, which when suitably equipped are then

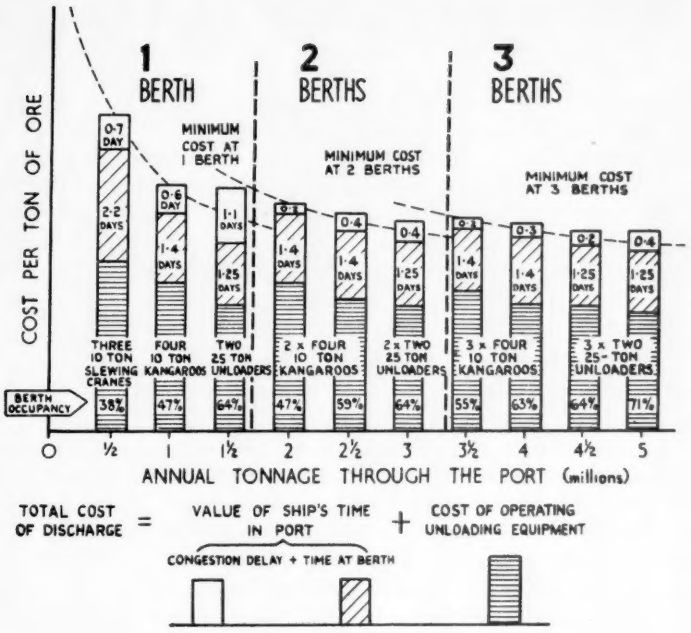

FIGURE 3. Installations for various tonnages. Examples of equipment (continuously manned) giving the lowest total cost of discharging ore from tramp ships.

adequate for tonnages up to 3–3½ millions. From then on three berths are preferable.

If, however, faster unloading proves practicable, the changes from one to two berths and two to three berths would be postponed to greater tonnages, and costs would consequently be lower. The broken lines labelled "minimum" cost in Figure 3 show the trends of the minimum cost when there is no limit to the capacity of equipment which can be used.

Turn-round times must be reduced very considerably below their present level. At ports handling 1 million tons per year upwards, 1½–2 days should be enough for the average 8,000 ton tramp vessel if the most economic installations are provided.

CONCLUSION

As a result of the research, only parts of which have been referred to here, it was possible to make firm recommendations

regarding such matters as the value to the industry of having ore-carriers specially designed for the rapid discharge of ore; the best sizes of such ships and the conditions in which they could operate most profitably; the benefits of using deep ports rather than shallow ones; the advantages of handling large tonnages and the best type of discharging equipment to install at ports, depending on the tonnage to be handled. All these were presented in a quantitative form so that alternative policies could be evaluated to help the executive decide what action to take to reduce to a mimimum the total cost of the complex operation of importing ore from abroad.

The Institute of Cost and Works Accountants

The fourth residential summer school of the Institute of Cost and Works Accountants was held from 21 to 26 September on the subject of financial management.

It was a little disappointing, even if not surprising, how little was said about the use of costs in assessing the value of technical changes. This is the area where operational research and accountancy should meet but which, in the view of the operational research worker, is too often neglected by the accountant. The first speaker, Dr. Risk, did indeed stress the importance of preparing accounts in an objective form as a weapon in budgetary control; he was referring, however, to control by larger top management distant from the actual scene of operations rather than to "on the spot" controls. Mr. Kennedy also had some interesting thoughts on the analysis of accounts in his paper on comparable costs, although there is only a limited usefulness in comparisons based, as he suggested, on percentage ratios, rather than actual money, spent under the various headings.

The main emphasis was on such matters as the effects of taxation and death duties, the problems of raising capital and the proper assessment of profit in terms of rising capital costs. It is perhaps salutary for those doing research into the technicalities of production to be reminded that it is considerations of that sort which often have the last word in managemental decisions.

The 1953 Proceedings of the 8th Annual Industrial Engineering Conference of the Society for Advancement of Management, *Time Study and Methods for Lower Total Costs,* are now available at a price of $5.00 from the Society for Advancement of Management, 74 Fifth Avenue, New York 11, N.Y., U.S.A.

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ABSTRACTS

Quality Control Aids in Steel Processing Control.

WADE R. WEAVER (Republic Steel Corporation).

Blast Furnace and Steel Plant, February and March, 1953; **41** (2) & (3), 198-202, 307-310.

Some possible applications of statistics to data arising and collected in the course of production are considered.

Owing to variation in yield of prime quality sheet rolled from different ingots an allowance is usually made to ensure that each ingot yields not less than the required number of sheets which must be of exact dimensions. This allowance results in short lengths of sheet being left over which may be usable only as scrap. The construction of frequency distributions and control charts enabled the sources of variation to be analysed according to quality and weight of ingot, taking account of factors such as furnace-size and different open hearth crews, both of which were found to affect the proportion of good quality steel per ingot, and mould dimensions which were found to cause unnecessary variation in ingot weight. These studies enabled improved yields to be achieved amounting to 2-7 per cent. due to reduced variation between furnaces and 3·9 per cent. due to improved variation in practice between crews.

Having brought ingot weight and quality under suitable control further studies along similar lines resulted in better control of the weight of slabs and end products.

Towards a Philosophy of Operations Research.

GERALD HINDRICHS.

Philosophy of Science, 1953; **20,** 59.

Hindrichs starts from the definition in Kimball and Morse (Methods of Operations Research) "Operations Research is a scientific method of providing executive departments with a quantitative basis for decisions regarding the operations under their control". He points out that this definition is wide enough to include, for example, time and motion study; he therefore seeks other evidence of novelty. An operations research group is set up to give advice to executives on *means* of carrying out agreed policy, and "where the quantitative understanding of the means necessary to achieve those ends leaves off, the operations researcher's competence stops". He points out, however, that scientists are by no means agreed as to what constitutes the scientific method; definitions based on physics and chemistry, for example, reduce

psychology to the level of a pseudo-science. This leads him to find the novelty in the multi-discipline approach of much operations research, where the workers are together as a team rather than a collection of specialists. This may not be a new idea, but it is new in practice in the study of operations as a whole, where "the real problem may not be just the sum total of the problems that have hitherto interested specialists in sealed-off fields of academic research". The fact that the operations research worker must try to get a genuine measure of the end results sought and the efficiency with which they are attained must eventually lead him to philosophical analysis of problems of genuine aims and of the means with which they are sought, to cross checking of solutions for their side effects, and for consideration of the wider issues than the merely quantitative and technical.

Can Scientific Sampling Techniques be used in Railroad Accounting?
Railway Age, 9 *June*, 1952; 61-64.

Operations research is defined as the application of patterns which the scientist has found useful in solving his own problems to help solve problems in areas such as transportation, production, administration or accounting.

As an example an investigation is described into the settlement of freight waybills between different railroads. A stratified sample of waybills was examined and the settlement shown from the sample agreed within $100 in a total of over $64,000 with that shown by a complete count of all the waybills over the period under review. The method of sampling is given, the overall sample being 9 per cent. of the waybills. The cost of the total count is estimated at $5,000; that of the sample at under $1,000.

A similar comparison of a sample with a complete count of commercial passenger tickets gave equally close agreement, again with substantial saving in cost.

Other problems in railroad operation where O.R. might help are suggested, and emphasis is laid on the importance of the O.R. worker and the railroad man working together for the successful solution of such problems.

Operational Research.
The Economist, 15 *August*, 1953; **168** (5738), 465-467.

After a general description, illustrated by a case study, and a short review of the progress of operational research this editorial article comments on its possible value and on some of the difficulties it may meet in becoming an established tool of management.

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Some Effects of Paid Sick Leave on Sickness Absence.

R. A. DENERLEY.

Brit. Journ. Industrial Medicine, 1952; **9,** 275-281.

A study is made of records of absence due to sickness before and after the introduction in 1948 of a scheme of sick pay in a large company controlling many factories in different parts of the country. Comparative figures are also given of absence in another large company which had been operating a sick pay scheme since 1928 for its "established" workers (these forming not more than half the workers who were at least 24 years of age and had completed three years' service).

In both companies payment during sickness appears to be associated with an approximate doubling of absence due to sickness. The gross figures are complicated by such factors as the introduction of the National Health Service in 1948, stricter insistence on the production of a medical certificate for sickness leading to a more accurate classification of the reasons for absence, the effect of age, coupled with the possibility that the taking of more sick leave when medically advisable when young may reduce illness in later life.

Some detailed figures are given to provide an assessment of the importance of these factors as far as possible. The possible effect of increased feelings of satisfaction and loyalty to the firm are regarded as outside the scope of the article.

BOOK REVIEWS

Nationalized Industries—Relations with the Public.

THE ACTON SOCIETY TRUST.

London, 1953. 39 *pp.* 2*s.*

A new feature of modern life is the number of industries whose operating policies are expected to be decided in conformity with some rather nebulous "national interest", instead of being moulded by the classic conceptions of economics. If the balance sheet is not to be allowed to function as a measure of the effectiveness of the industry's operations, some other measure must be substituted. Here, one may suppose, is an open field for operational research.

The Acton Society Trust pamphlet on *Relations with the Public* is the twelfth and last in a series of studies in nationalized industry, and it deals with the important problem of how the Boards can determine what the consumers' interests are and how nearly they are being met. The pamphlet refers to the work of the Operational Research Division of British Railways and of the Development and

Research Section of London Transport, both of which are experimenting with new methods of measurement, particularly to determine the consumers' part of the "public interest". The general conclusion, however, is that "it is regrettable that the industries should have made no systematic attempts to discover public preferences, or the attitude of the public to services provided", and the need is stressed for an extended use of consumer research carried out on an adequate basis.

The pamphlet reviews the existing mechanisms for ascertaining consumer requirements, especially the public relations departments of the Boards and the Consumer Councils. The difficulties of the Boards in dealing with ill-informed public criticism are fairly presented. Reference is made to the rôle of independent enquiries, such as the one being described; the more extensive use of such investigations is suggested, but a warning is rightly given of the difficulties of producing generalized conclusions applicable to such vast and complex industries. R. T. E.

The British Cast Iron Research Association's Operational Research Team.

The Council of Ironfounding Associations, London, 1953, 12 *pp.*

This pamphlet describes the principles on which the team has worked during the first two years of its service. It is no criticism to say that the term "Operational Research Team" is in some ways a misnomer, since the team's function appears to be frankly to give advice about operational problems rather than to conduct research into them. In so far as the advice is based on research findings, however, it performs a vital function in ensuring that research results are put to practical use.

The Tools of Social Science.

JOHN MADGE.

Longmans, Green & Co., London, 1953; 308 *pp.*, 25*s.*

The contrast between the sophisticated and successful techniques now available to man for the control of his physical environment and the relative incompetence with which he handles his relations with other men has often been pointed to. Comparatively few commentators even regard this latter as a scientific problem anyway and for this attitude social scientists themselves cannot altogther escape blame. Nevertheless as Mr. Madge points out in this book, social science is no longer in its earliest infancy, and it is becoming increasingly difficult for the physical scientist to shrug off its results as lacking the established objectivity he may demand

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in his own sphere. For this reason such a book is over-due and it is no criticism to hope that others may follow attempting to set out the basic techniques involved in the scientific approach to human problems and to unify them under common principles.

After a preliminary discussion on the methods of social science in general in which its logical and philosophical bases are examined, successive chapters deal with Documents, Observations, Interviewing and finally Experiments. Naturally a degree of compression is inevitable where one has to consider everything from e.g., the opinion poll interview which may last a few minutes to psycho-analysis which may last seven years. In spite of, or perhaps because of, this the book is stimulating and extremely readable. It concludes with a brief chapter, written after the rest had been set up in type, on the limits of social science. J. M. M. H.

The Hulton Readership Survey—1953

Hulton Press, London, 1953; 50*s*.

Media research is perhaps marginal to operational research, but a publication which claims to be carried out "in accordance with accepted techniques of modern research" invites a study of the methods, even if the field covered is not the normal concern of this journal.

As has been pointed out earlier in the *Operational Research Quarterly,*[1] "readership" studies could make an important contribution to the efficient placing of advertising matter. Nothing need be added to nor subtracted from the comments then made—the new **Hulton Readership Survey for 1953** follows the same lines as before. The shock which the methods used apparently sustained in 1952 have had, so far, no effect. The claims made in the new edition are equally as extravagant although more has become known about the limitations of quota sampling during the year.

Early this year, MOSER and STEWART read a paper before the Royal Statistical Society which demonstrated that the variance of quota sampling (making certain assumptions about replication which may be somewhat liberal) was on average about twice that of random sampling. Yet the Hulton Readership Survey claims that the variance of a quota sample is "much less" than that of a random sample.* They also claim that a system of indicating reliability of their figures "make(s) it unnecessary for the ordinary user . . . to undertake the quite complicated calculations needed to arrive at the statistical limits of error". Even a well designed and replicated

*In fact they compare the "standard error" of a random sample with the "probable error" of their sample—but the term "probable" does not appear to be used in any technical sense.

quota sample cannot give exact estimates of error, and it would be certainly impossible for anyone, given only the figures in this publication to make any calculations of statistical error whatever.

When one examines the methods in more detail, it becomes more difficult to ascertain exactly what has been done, and other doubts about the methods emerge. For example, it is stated that there was a random selection of electoral divisions as sample areas, and included amongst the controls was an "industrial classification". It is not stated what form of industrial classification was used—whether this applied to areas or to individuals—a very important factor. Nor is there any clear statement as to what exactly the "electoral divisions" were, whether they were constituencies, wards or polling districts. If constituencies were first classified as either urban or rural, then doubt arises as to how this was done, since very few (if any) constituencies, no matter how rural, do not contain an urban part.

With a concept as difficult as "readership" it is more likely that the main errors are not sampling errors, but errors due to the interviewing conditions and the form of the questions. By changes of wording or even only of order, it might be possible to change the proportion of readers of different publications whilst apparently giving the same set of data. There is no indication that the stimuli (different publications) were randomized or presented in any designed form which would avoid any effect due to ordinal position.

Studies of the effect of television upon the leisure pursuits of viewers have usually found that their reading has declined.[2] The Hulton Readership Survey, however, shows the reverse result. A confounding of viewing with age does not seem to explain this peculiarity. Regular beer drinkers also read more than those who drink beer occasionally! Could it be that there is a class of respondent who finds it more difficult than others to say "no"?

All operational research workers will recognize that it is undesirable to state all the technical limitations of a study in a document which is intended primarily for administrative action. But even making full allowance for this fact, the presentation falls far short of compliance with the standards for reporting sample surveys recommended by the United Nations Sub-committee on Sample Surveys.[3]

References:

[1]Media research reports, a critical notice. *O.R.Q.*, 1952, **3** (4), 72.

[2]SWANSON, C. E. and JONES, R. L. Television owning and its correlates. *J. Applied Psychol.*, 1951, **35** (5), 352.

[3]Statistical office of the United Nations. *Statistical papers, Series C. No.* 1 (revised).

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EDITORIAL NOTES

The Operational Research Club has become the Operational Research Society. The Committee's recommendation was endorsed by the annual general meeting on 10 November, and the metamorphosis is now complete. The following statement has been issued to the Press:

The increasing interest in operational research in this country has caused the Operational Research Club, hitherto a deliberately restricted group of scientists meeting more or less informally, to reconstitute itself formally as the Operational Research Society with no numerical limit on membership. Members must still, however, be engaged in some form of operational research "whether or not it is so called". The subscription rate is 25s. per year, which includes the Operational Research Quarterly. The honorary secretary is B. H. P. Rivett, 2, Grosvenor Place, London, S.W.1.

The first Chairman of the Society is Dr. O. H. Wansbrough-Jones (*Chief Scientist, Ministry of Supply*)*; committee members are:* Dr. T. E. Easterfield (*Department of Scientific and Industrial Research*), Sir Charles F. Goodeve (*British Iron and Steel Research Association*), Mr. Donald Hicks (*National Coal Board*) *and* Mr. A. W. Swan (*Courtaulds Ltd.*).

The change is not merely one of nomenclature. It reflects the

widened scope that the Club has had to accept, and the wider nature of the task that lies before it. The Club was founded in April, 1948, when a few of those who had taken part in the successful development of operational research during the war, and who had had occasional, informal meetings to discuss their work, agreed among themselves to act as convenors. The object of the Club was thus little more than the provision of a means of informal discussion between scientists engaged in operational research, and a restriction on membership was a natural step for the preservation of the intimate and informal nature of the meetings.

Six meetings have been held between October and April every year since the Club's formation, all at the rooms of the Royal Society in London. They have discussed the use of operational research in many industries and services, including agriculture, cotton, steel, boots and shoes, coal, electricity, livestock breeding, building and transport.

The possibility of advancing knowledge of operational research in science and industry, as well as discussing it, was not lost sight of, however. One of the earliest ventures in this direction was in the autumn of 1949, when encouragement and support were given to a series of lectures on operational research, organized by Professor E. S. PEARSON at University College, London. The widespread support that these lectures enjoyed was a proximate cause of the establishment of this *Quarterly*, whose first issue appeared in March, 1950. Another recognition of the Club's wider task has been the conversion of one meeting into an "open" meeting annually since 1951, when aspects of operational research of relatively wide scope are discussed by members and guests; these meetings are reported in the Press. The topics at the three meetings were respectively: the *Measurement of Productivity*, *Marshalling and Queueing*, and *Men and Machines in Transport Systems*. The subject for 1953 (see page 60) is to be *Capacity, its Meaning, Measurement and Specification*, which is to be disscussed in conjunction with the British Institute of Management.

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Apart from the Club's own official efforts, its members have given many lectures and papers on the subject in this country and in the United States. The work of Professor MATTHEW at Birmingham University is well known—a report of his latest post-graduate course will be found on page 77 of this issue.

The existence of the Club has been conincident with a considerable growth in interest in and use of operational research in industry, as the paper by GOODEVE and RIDLEY showed in our June issue (*Operat. Res. Quart.*, 1953; **4** (2), p. 37). *Post hoc ergo propter hoc* would be a poor principle in operational research, but it seems reasonable for the Club to claim some credit for this development. But in claiming credit, it accepts duty, which the conversion of Club into Society recognizes.

This recognition entails three main changes:

Membership: the numerical limit placed on the Club's membership is abolished, though members must still satisfy the Committee that they have what is regarded as a professional qualification. This cannot be more closely defined than by saying that they must have been engaged in operational research work, whether or not it is so called.

Constitution: the loose, informal nature of a Club of less than 100 members is inappropriate for a larger body, and a written constitution for the Society was approved when the conversion was agreed. This gives the Society a legal personality, and constitutes it a non-profit making body—"charitable" in the legal sense—guided by an executive Committee of five, elected by the members of the Society and retiring in rotation.

Aims and Objects: a larger body needs to define its aims and objects more precisely. These are set out in the constitution as "the advancement of education through the provision of training in and the promotion and adoption of operational research". The specific means envisaged are: "(a) lectures, classes, discussions and publications; (b) the promotion and organization of research projects; (c) the encouragement of contact between workers in all relevant fields of enquiry". Presumably the Society's meetings and its support of

educational ventures such as those of Professor MATTHEW, and Sir CHARLES GOODEVE's recent papers in America and to the British Institute of Management in London, will continue as its main efforts. The larger funds and the wider basis that an enlarged membership will supply offer an encouraging prospect of an effort on a still broader front.

OPERATIONAL RESEARCH SOCIETY

The annual "open" meeting for this session will be held on 19 February, in conjunction with the British Institute of Management at 8, Hill Street, London, W.1. Three speakers will introduce discussion on *Capacity, Its Meaning, Use and Measurement.* The meeting will begin at 2.30 p.m. Members of the O.R. Society are invited to bring guests, and other non-members will be welcome. Non-members (or their hosts) are asked to notify the Secretary of their intention to attend.

The date of the March meeting is yet to be fixed. It is hoped that Mr. ELLIS A. JOHNSON, Director, Operations Research Office, Johns Hopkins University, will speak on some aspects of O.R. in the U.S.A.

On 12 April Mr. A. D. VAN REST, Ministry of Supply, will speak on *Inspection.* Mr. A. W. SWAN will be in the chair. Both the March and April meetings will take place as usual at the rooms of the Royal Society, Burlington House, London at 5 p.m., preceded by tea at 4.45 p.m.

ROAD PLANNING

Following the comment made in our last Editorial Notes on operational research in road development, we have been informed that the Road Research Laboratory attempts to get over the difficulties of the lack of trained operational research staff in highway authorities by their publications and by holding courses on traffic subjects. This must help considerably in ameliorating the difficulties to which we referred. We are also pleased to learn that many highway authorities are aware of their need for trained staff and that a number of them, e.g., Bucks County, Kent County and London County, have staff who specialize in traffic and accident problems.

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COMMUNICATION PROBLEMS

The second meeting of the present session of the Operational Research Society took place on 17 *December with* Mr. R. T. EDDISON *in the chair. Three short papers were given, and are reported below.* Mr. B. H. P. RIVETT *and* Mr. E. C. WILLIAMS *are of the National Coal Board and the Admiralty respectively,* Mr. B. D. HANKIN *is lately of the Army Operational Research Group.*

Underground Communications

by

B. H. P. RIVETT

THE WORK of the National Coal Board on underground communications is a result of the Creswell Colliery disaster. The disaster had two main causes: firstly, the ignition of a rubber conveyor belt with the consequent emission of poisonous gases, and, secondly, failure to communicate to the men in the pit the degree of the emergency.

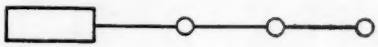
The object of this study in communications was defined as being to consider the adequacy of underground communications and personnel warning systems. It was clear early on that the work would be at the technological level, in that the survey would be concentrated on the layout of underground telephone systems and the possibilities of using alternative warning devices. It was also clear that the investigation would fall into two parts. One would be a day-to-day study of the use of telephones in collieries, and the other would be a study of the use of the telephone system in an emergency.

Day-to-day Use of the Telephone System.

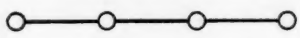
There are three types of telephone lines in use underground:—

(i) Lines connecting single telephones to the Exchange. (This Exchange may be either on surface or underground.)

(ii) Party lines connecting a number of telephones to the Exchange.



(iii) Party lines connecting a number of telephones to each other, but which are not connected through to the Exchange.



The first collieries visited had relatively simple layouts. From the pit exchange telephone lines radiated on which there were either single phones or a number of phones. There were also party lines not connected to the exchange.

The total time for the operation of making a call on these lines can be broken down into four components:—

(i) The time for the exchange to answer an incoming call.
(ii) The time the exchange takes to handle a "through" call.
(iii) The time for an extension to answer a call.
(iv) The talking time.

Calls were logged by observers at the exchange switchboard and elsewhere underground, over a period of three weeks, and were broken down into these four component times. The distribution of delay times for each of these components was, in general, of the Poisson form, and the single parameters (the mean delay times) for the above four components were, respectively, 19 seconds, 17 seconds, 26 seconds, and 36 seconds. It proved very difficult to discover what factors influenced the mean delay time; in fact, only 3 such factors were found. The time for the exchange to answer was dependent on the shift, and the improvement resulting from the use of a full-time operator on the exchange was quite noticeable. The time for extensions to answer depended on the type of work going on by the telephone, and the type of work also influenced the talking time.

The analysis also showed that a straight breakdown of each single call into these components could be misleading. In many cases, a large number of calls were devoted to the same incident, and calls were repeated until a successful result, such as the finding of an official, was obtained. The total time spent within these groups of calls was closely related to the purpose of the group of calls.

Besides being related to the shift, the time for the exchange to answer was also closely linked to the rate at which calls were coming on to the switchboard, and it was possible to estimate the chance of an extreme delay from this rate. Reducing the chance of an extreme delay is very important in the case of an emergency. An

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analysis showed that a large proportion of the calls coming to the switchboard did not in fact need the operator, and the technical action necessary to keep these calls off the switchboard and thus reduce the chance of an extreme delay was indicated.

All the data collected in the day-to-day study of the communication system were necessary, when the emergency use was considered. It has not yet, however, been possible to obtain a measure of the adequacy of a telephone system in day-to-day use in a colliery. Ideally, it should be possible to show the improvement at coal output which could come from revising the lay-out of the telephone system, but this has not yet been effected.

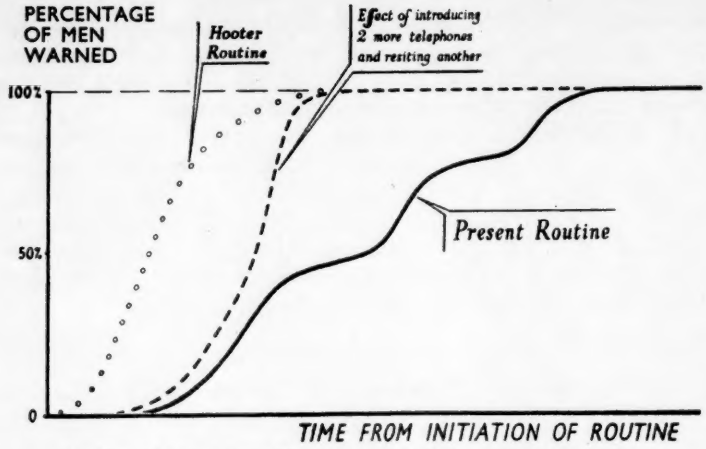
Emergency Use of the Telephone System.

It is not possible to carry out any experiments at a colliery into the use of the communications system in emergency. Consequently, this part of the work was largely paper study. Each colliery has its own routine for use in an emergency, and it was possible to break this routine into its component stages.

As an example of the method used, one can consider the routine used at one of the pits. This is: the management contacts the deputy in each district in the pit, the deputy is given instructions as to what he should do, and how the men should come out of the pit. The deputy then goes round his district, sending runners where possible and passes on this information to all the men under his control. It was possible to estimate how many men would be warned in any given time from the initiation of this routine. Test calls were made to test how long it took to contact deputies, and a wide variability both from district to district and from shift to shift was apparent. In fact, the time taken to contact the deputy was fifty times the minimum. It was clear that re-siting of telephones and the introduction of some fresh phones were necessary to cut down the high delays in this part of the routine.

Over a period of a few shifts observers noted the position of all the men in the pit and were thus able to draw up a man-power map. Working from this map, estimates were obtained, and the time taken by the deputy and the runners to contact every man in each district, and hence curves could be produced showing the number of men warned as a function of the time that had elapsed since the initiation of the warning at this particular colliery.

It was estimated that the introduction of two telephones and the re-siting of one other phone would cut down the time to warn all the men by 50 per cent. An alternative warning procedure using hooters was considered and it was estimated that the total time to



Number of Men Warned by Various Methods as a Function of Time since Initiation of Warnings.

give a verbal message to all the men under this routine could be brought down by 75 per cent.

Sub-exchanges.

After the first few pits had been studied, it was thought that the solution to the problem of getting an emergency message out over a telephone system in the shortest time might be the installation of sub-exchanges on the lines from the main exchange. These sub-exchanges would be connected to a number of single phones or other sub-exchanges.

One of the pits visited in the closing stages of the investigation had this lay-out. Unfortunately, although when calls are promptly answered at sub-exchanges this system does show up as being extremely efficient, there were in fact a number of unanswered calls at these sub-exchanges. This meant not only that there was a high probability of extreme delays in warning the men, but also it meant that the methods of analysis previously used were not applicable. When a sub-exchange does not answer a call, alternative action has to be taken in getting a message to that sub-exchange, or past it, and the problem is one of the random walk type, which is being tackled by Monte Carlo methods.

Technical Off-shoots.

It is interesting that this work has stimulated other work outside the fields of operational research. It became clear in the

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investigation that the underground telephones in use had not been designed to give effective transmission in the ambient noise levels. On some telephones it was just impossible either to hear the bell or to make effective communication. Work is now proceeding to develop suitable telephones for use underground. It was also obvious that a great deal of time was wasted on the telephone because men had not been trained to use the phone properly, and, in particular, a great deal of talking time was wasted because people did not identify themselves, or the position from which they were talking. The experiences gained in the investigation are being used in the preparation of a training manual on the use of telephones.

Communication and Control of Military Forces

by

B. D. HANKIN

THE TACTICAL success of military forces clearly depends to a large extent on the way they can be handled relative to those of an enemy. The quick handling of a fighting force by a higher commander depends not only on the speed of their vehicles, but is greatly dependent on the speed and efficiency of the tactical planning and instructions affecting all arms which precedes an operation. It also depends upon the completion of many administrative arrangements to enable the force to move and fight. Communications in the Army exist for providing the commanders and staffs with this tactical and administrative control.

Object.

A military formation must be mobile and flexible and must be self-contained, with its own communications. But if the task of a force such as a division is primarily to fight, the number of men who can be used to provide and maintain communications is necessarily limited both in quantity and quality. Our object was to provide data which would help the War Office to decide how the Royal Signals men and equipment should be employed to the best advantage.

A radio operator is not normally trained to lay telephone lines, a despatch rider does not know how to operate a telephone switchboard. How suitable were the existing proportions and structure of tradesmen and if new methods of communications such as the beam wireless telephone system (known in the Army as "Radio Relay")

was to be introduced, where was the best place from which to take the manpower to operate it?

Method.

We chose the division as our unit for study and most of our work was carried out in armoured divisions in Germany. A division at war consists of about 17,000 men. It is controlled from divisional headquarters where the divisional commander (a major general), and the divisional staff exercise command.

There are two brigades each controlled by a brigade headquarters. To simplify our problem we concentrated on the level of command between division and brigade.

We came to the conclusion that all the stages in mounting and carrying through a successful operation involve the transmission of a commodity we described as "military information".* It is a process which takes place both up and down the chain of command.

The methods of transmitting "military information" which are in use at this level are:—

(a) Personal Contact. *Includes visits by general, liaison officers, order groups and conferences.*
(b) Radio Telephony.
(c) Line Telephony.
(d) Despatch Rider. *Includes written messages, maps and documents.*
(e) Morse Code by Wireless.

We considered that three important things associated with any piece of information were its quantity, urgency and security. Its value to the battle was also important but we decided to concentrate in the early stages on these three and particularly on the quantity.

If we were to compare the quantities of military information carried by the various means we had to find a unit of measurement which could be common to all.† We adopted a unit of our own which we called "Useful Words". This could be common to speech by wireless or telephone and also to written documents. The difficulty of course lay in defining what we meant by "useful". Not without difficulty this definition was formulated: "Words may

* We defined this as: "Any knowledge which is relevant to the prosecution of the war and which reaches the minds of those in control at any level and by any means".

† Shannon and Weaver's Mathematic Theory of Communication introduced a "binary digit" or "bit" as a unit of information. This was considered but rejected as impracticable for the early stages of the study.

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be counted as useful if in the circumstances they are judged to have military importance, and if it is considered reasonable that two informed and busy individuals might use them in passing information from one to the other, when seated on opposites sides of a quiet secluded room". This succeeded in excluding all the procedure associated with getting through, chit-chat if found, and repetitions due to the imperfections of the medium.

In order to establish the broad facts as to how a division was controlled we decided to try to measure all the information flow by all means at the division to brigade level on full-scale manœuvres lasting nearly a week. The only completely objective method of doing this is to make recordings of every single radio and telephone transmission and every meeting between staff officers. The time required for analysis of these recordings makes this impracticable. We found a way which was sufficiently accurate for our purposes. By a sampling system we measured the "voice occupancy" of all the radio nets and telephone lines and at the same time made tape recordings of many hours of each. Subsequent analysis of the recordings provided factors with which we could convert "voice occupancy" into useful words. We tackled personal contact flow in the same way. We made recordings of order groups and deduced a factor which could be used to convert the length of the discussion measured in minutes into "useful words". Despatch traffic was dealt with by analysing the contents and noting the flow of typical packages. To do all this in a self-contained manner on a twenty-four hour basis needed a team of about twenty-four men and eight vehicles.

Results.

The results included the following:

(a) Communications depend to a very large extent upon the integration of staff and Signals and upon the standard of training and equipment of both. It is the staff—Signals—equipment combination which produces the results. Search in all three must be made to gain improvement.

(b) The estimated proportion of useful words carried by the various methods between Divisional H.Q. and forward units on the whole 4-day exercise is shown in Table I.

(c) Personal contact was an extremely important method of passing "military information". compared with other methods it ranks very high when conditions allow its use.

(d) Wireless nets were not loaded to their capacity except for very short periods—of all the words spoken by wireless, about one-third could be classed as "military information".

(e) The use of Morse code (on which every Royal Signals wireless operator spends much of his training time) made a negligible contribution to the control of the division on this exercise.

TABLE I

	per cent.	No. of useful words
Personal Contact . . .	56	467,000
Radio Telephony . . .	22	186,000
Telephone	11	87,000
Despatch Rider . . .	11	89,000
Morse Code . . .	Negligible	
	100	

We were able to make a number of recommendations which should help to obtain better control within the division without increases in manpower. Above all we believe that we have stimulated thought which will help the planners to realize what they are getting in terms of information passed and control achieved for the effort expended.

In conclusion I would like to stress that this work was a combined operation in the sense that our team included civilian and military members including military personnel serving in Germany and T.A. officers doing their fortnight's attachment. It would also be wrong not to place it in its perspective by saying that it is only one of a number of communication projects which are being tackled by other members of the Army Operational Research Group.

Communications

by

E. C. WILLIAMS

I PROPOSE to add two specific examples of communication problems, and then to speculate about a possible generalization of "battle" situations.

Radar Reporting.

The first specific example is a study of the capacity of the radar reporting system which was carried out by F. L. Sawyer, L. G. H.

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Huxley and myself during 1940. A similar study of the Royal Observer Corps system was subsequently done by R. G. Stansfield. The system consisted of:

(i) Radar stations which, having determined the plan position and height of aircraft as accurately and as quickly as they could, reported these positions by voice telephone to a filter room, in standard form.

(ii) The filter room which having co-ordinated the reports from one or more radar stations, determined the most probable position, track, and strength and height of the raid, and reported these simultaneously to the command operations room, the group operations room and the sector operations room.

There were thus the following communication or processing links:

(i) The determination by the operator of the position of the aircraft at the radar station.

(ii) The passage of that information in the form of plots by voice to a plotter in the filter room.

(iii) The filtering process, which had to be introduced because of the inaccuracies in bearing in the radar stations of that day.

(iv) The passage of those filtered tracks by voice to plotters in the various operations rooms.

The capacity of each of these links was measured in order that they might be matched as well as possible. At each stage various detailed improvements could be, and were, made. This, although adventurous at the time, was, in retrospect, a standard piece of communication systems capacity analysis—although it did include study of the human operator throughout. But the general and quite obvious point which emerged was that in a system of this type there is a saturation limit. The interesting thing was that this saturation limit was much lower than had been suspected and, most important, once it had been exceeded, not only did some information not get through, but even that which did get through was incorrect. The only way to maintain a truthful system was to degrade the input—in other words, to group the information on the input side so that the number of separate bits of information which were being passed through the system was below its saturation level. Thus one could produce a system which although it produced a coarser answer as the situation became more complicated, it at least retained the merit of truthfulness.

Aircraft Carriers.

The second specific example is a very similar one concerning action information organization aboard aircraft carriers. The operational procedure was basically the same; there are some differences in the gear. As one would expect, the measurements of similar parts of a similar system produce similar answers. However, the interesting part of this particular investigation was the revealing of a "mis-match" between on the one hand the command structure (and the current impression of the capabilities of the command) and, on the other hand, the capabilities and capacities of the gear. This was an example of the fact that the way in which one commands an action depends as much upon the capabilities of the equipment that is available to allow the command to be exercised, as it does upon the way in which one would like to command. The amount of detailed command that one man can exercise depends on how much detailed information can be presented to him, and equally upon his capacity to comprehend it when presented—which in turn, depends upon the rate at which the information is changing.

Generalized "Battle" Situations.

The generalization of "battle" situations is still in an early stage of original formulation by Dr. E. R. R. Holmberg of my Department, who drafted the paragraphs below, and who, I hope, may shortly publish a fuller paper on the matter.

The objectives of any military combat may be defined as:—

(a) To locate targets,
(b) To destroy them.

This definition of objectives can be applied, with some elasticity in the meaning of the terms, to very nearly all military engagements whether large or small, or whether on the tactical or the strategical scale. The objective has been deliberately divided to indicate first, that there is a problem of information, and second, that energy must be expended in destroying the target. In destroying the target there is a second information problem, that of aiming, or predicting, and this will in general be of the same order of magnitude as the first.

It is common knowledge that success probability—for example, a detection probability for an anti-submarine search equipment or probability of strike for a gun fire or guided missile system—is linked to the energy requirements for a kill in such a way that the greater the information the less the energy required. For example, if we are shooting at a man with information (i.e., aim) good enough to select a vital organ, the expenditure of energy is small—say, that

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needed to accelerate one ounce of metal to a velocity of 1,500 ft./sec. —about 10^{-7} kWh. If, however, the man is sitting in an aircraft 2 or 3 miles away, we might need ten rounds of fire with shells weighing 100 lb. each, and the kill needs about 300 kWh. reckoning explosive energy alone. Thus the lack of information implied in the increase of the average error from an inch to ten yards or so corresponds to an almost astronomical increase in energy requirements.

The next step is to estimate the physical size and cost of complete equipments, including power supplies, fuels and so on:

(a) to gather the information and to communicate it,
(b) to transport the destruction energy from base to target.

Experience and intuition suggest that, at any time in technological progress, the "know-how" roughly defines the relationship between information rate and equipment size in the sense that the bigger the information rate the bigger the equipment. The results so far seem to suggest that we may be able to go further and define an absolute measure of the equipment size needed to achieve a given information rate. This possibility merits the closest study, but it will be realized that it is difficult.

On the action side, as opposed to the information-communication side, the problem is better understood, at least when the energy is derived from conventional sources. The relationships between equipment size and power output, between fuel and propulsion weight, and total and available energy, are well known, so that the data necessary for calculating the cost of producing a given destructive effect at a given distance from base, within a given time, are available.

The next step is obvious. We have to find that best combination of action and information which minimize the cost of a "kill".

One could begin to extend this energy-information exchange concept to wider fields. Since in practice we can never ensure that we shall win every engagement we are obliged to give thought to the whole set of engagements of which the country's resources are capable. Then assuming that our strategic objects have been correctly stated, there are usually a number of different ways in which these objects could be obtained. Which is the better? These broad fields are, of course, though fascinating, by far the most difficult to plough with the small tools that we have so far been able to develop.

These three papers are published by permission respectively of the National Coal Board, the Scientific Adviser to the Army Council, and the Admiralty.

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ABSTRACTS AND REVIEWS

Die Ablauf- und Planungsforschung (Operational and Planning Research).

MANFRED KNAYER (Consulting Engineer).

Rationalisierung, October 1953; 273–276 (*In German*).

The history and methods of O.R. are discussed briefly and a few examples are given.

While the term operational research has not been much known so far in Germany, some work of similar kind has been in progress over a longer period. The so-called Grosszahlforschung (multitude research), originating from the steel industry, has proved useful also in other branches. A frequency analysis of the sales of window glass showed that the distribution of the widths of the plates followed a logarithmic normal curve, a fact to be considered in production planning, stocks and sales policy. A minor example are the reports of salesmen in a large enterprise. Although turned in regularly their survey took too much time because the reports were drawn up differently by each agent. The order of items was standardized and symbols were used at the bottom of the sheets to show the market conditions. By positioning the reports one above the other, the sales manager was able to survey the situation at a glance.

The evolution of O.R. at some degree is reflected by the number of publications which has risen from 2 in 1944 to over 60 in 1951.

Some Theoretical Aspects of Road Traffic Research.

J. G. WARDROP (Road Research Laboratory).

Proc. Inst. Civil Engrs., June 1952 (2); 325–378.

Some of the mathematical and statistical aspects of the disposition and behaviour of road traffic which are of importance in research are considered. It is shown that vehicles can simultaneously be regarded as distributed at random along a road and in time. Frequency distributions of speed for a given traffic stream are of two kinds, one associated with successive vehicles passing a point and the other with successive vehicles along a road at an instant. The corresponding average speeds generally differ by 6–12 per cent.

A formula is given for the frequency with which vehicles would overtake one another if there were no interference with overtaking.

Increases in the amount of traffic (the flow) generally produce corresponding decreases in speed. Capacity is defined as "the flow which produces the minimum acceptable average journey speed".

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Delay and capacity are discussed in relation to traffic signals, and it is shown that the shortest practicable cycle does not necessarily result in the minimum average delay. The randomness of traffic can cause very long delays at traffic signals.

When there are alternative routes which a traffic stream can follow, it may divide itself between them. The consequences of two possible rules governing this division are considered.

"Before-and-after" studies are discussed, and a statistical test for the genuineness of a difference in, say, average journey time "before" and "after" is given.

Train Arrivals: Handling Costs, and the Holding and Storage of Raw Materials.

M. D. J. BRISBY and R. T. EDDISON (B.I.S.R.A.).

J. Iron & Steel Inst., October, 1952; **172,** 171–183.

The sizes of trains and incidences of arrivals at iron and steel works are examined to find out how these affect the capacity of reception sidings required to accommodate incoming wagons. The works transport system is considered in its function as a buffer mechanism for evening out fluctuating arrivals to cater for a reasonably constant level of consumption.

Two alternative methods of holding buffer stock are examined —the holding of wagons loaded in sidings and the immediate discharge of wagons to some form of ground storage, the raw materials being reclaimed later as required. The cost of the first method depends on the length of time the wagons are held; the cost of the second is almost independent of time. A "Monte Carlo" type of approach is used to determine an economic balance between these two methods, given particular rules of operation and the siding capacity required to achieve that balance.

The House that Fact Built—A Case for Operational Research in Housing.

BASIL MARRIOTT.

"*The Builder*", 12 *September*, 1952, *No.* 5717; 19 *September*, 1952, *No.* 5718; 26 *September*, 1952, *No.* 5719.

These three articles are written by a qualified architect and are intended to make a case for operational research into housing. "Insufficient study", says Mr. Marriott, "has been given to the question of what the dwelling should *do* before how, and of what, it should be made". He illustrates his approach with reference to several functional aspects of houses in general giving as examples the disposal of refuse, storage, furniture, recreation, and heating. In

each case current alternative solutions are briefly set out and further research by a mixed team is advocated. There are few operational research workers who would disagree with the author's belief in the importance of this approach, but he has not indicated just what such a team would do. Would they, for example, function as a research team or merely as a committee to decide between alternatives? Should the approach be experimental or inductive and on what basis should the data be gathered? Operational research, as a scientific approach to certain problems dependent on empirical study must be distinguished from a consensus of the opinions of a number of scientists.

A Method of Computing the Optimum Size-Limit for a Fishery.

K. RADWAY ALLEN (Marine Department, New Zealand).

Nature, 1 *August*, 1953; **172** (4370), 210.

In an exploited fishery the main function of a size limit is to ensure that the weight of the yield is a maximum but losses due to unrealized growth or natural death are a minimum. This letter indicates a method of determining the optimum size-limit from two readily obtainable statistics—the average weight of fish in the catch and the proportion of fish passing the limiting size which are ultimately caught.

Ratio Delay Technique.

J. R. DE JONG.

Tydschrift voor Efficientie en Documentatie, 1953; **23**, 230–238 (*In Dutch*).

The author explains the snap-reading method of making time studies introduced by L. H. C. Tippett some 25 years ago. The method is now more generally known as the "ratio delay technique".

The main field of application of this technique has been to supplement the conventional time studies necessary to establish pure time rates. A detailed account of some of these applications is given.

After a study of the accuracy of the ratio delay technique the author proceeds to discuss the relative merits of, (a) the conventional time study, (b) the production study with stop-watch, and (c) the ratio delay technique. It is shown that for long cycles the conventional time study is entirely adequate whereas for short cycles the production study and the ratio-delay technique are more suitable. Of these two, the latter is to be preferred since, for a given case, it requires considerably less time than the former.

The author ends with some applications of the ratio delay technique to problems in administrative and production departments.

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An Introduction to Linear Programming.

A. CHARNES, W. W. COOPER, and A. HENDERSON (Carnegie Institute of Technology).

John Wiley & Sons Inc., New York, and Chapman and Hall, Ltd., London, 1953; 74 *pp.*; 20*s.*

This book is divided into two parts: in the first ("An Economic Introduction to Linear Programming" by Cooper and Henderson) a numerical example is worked through in detail, while the second part ("Lectures on the Mathematical Theory of Linear Programming" by Charnes) presents the general case in formal terms.

A deliberately over-simplified problem is used as the example: a manufacturer preparing various mixes of nuts for sale requires a programme which will give him the largest profit. The prices of each kind of nut are specified, and there are certain restrictions on the contents of the mixtures and on the quantities which can be produced. Using the minimum of algebra the "simplex" method of computation is demonstrated, and an optimum programme (which happens to require the manufacturer to concentrate on making as much of one particular mixture as the conditions permit) is determined.

In Part II, Professor Charnes' lectures present a rigorous treatment of the subject, using matrix algebra. Degeneracy is discussed, and a procedure is developed to ensure that the computation will in fact lead to an optimal solution. D. G. O.

Psychological and Psycho-physical Studies of Craftsmanship in Dairying.

ROLAND HARPER.

British Journal of Psychology—Monograph Supplements, XXVIII. Cambridge University Press, Cambridge, 1952; 61 *pp.*; 9*s.* 6*d.*

In this monograph Dr. Harper has brought together and described most of the work that he and others have been doing on psycho-physical problems in food grading.

After a general description of the problems of this kind involved in craftsmanship in the dairy industry, with particular reference to cheese-making and grading, he goes on to survey the literature on psycho-rheological questions, and then presents in detail an analysis of experimental investigations which he and his colleagues carried out as part of a study of the psycho-physical experience of "firmness" in complex deformable materials.

The title, therefore, is somewhat misleading since the field of enquiry is severely limited and, as Dr. Harper states, "in many respects, dissatisfaction is felt with the lack of crucial hypotheses

and experimental tests of such hypotheses". In a new field, however, this is inevitable, and it has not deterred Dr. Harper from subjecting his experimental data to some rigorous and sometimes difficult mathematical analysis.

The operational research worker will be interested in the possibility of the practical application of the results of these fundamental experiments. He will want to know, in particular, how much help they give him in solving the problems of selecting and training craftsmen of this kind and of replacing all or part of the craftsmanship by instrumentation. The body of knowledge is as yet too small to answer these questions, except in a rather negative form, since the stage of crucial hypotheses has not been reached.

To the first question Dr. Harper's work certainly offers the hope that it may in the future be possible to devise more accurate selection tests for potential craftsmen, probably used mainly to screen out those unlikely to possess the psycho-physical sensitivity needed. Since dairy products are perishable and subject to continuous changes in their rheological and physical properties one of the difficulties of training craftsmen is that each lesson has to be taught with a different piece of "cheese" and therefore replication is extremely difficult. Although similar changes take place in the rubber which Dr. Harper had produced by the Research Association of British Rubber Manufacturers, these changes are not so great and do not take place so quickly and it should be possible in future to use similar materials to reduce the training period required.

To the second question Dr. Harper states categorically: "Let us not fall into the error of assuming, without sound evidence, that instrumental observations are necessarily superior to the unaided judgment of the experienced worker". No such sound evidence has so far been obtained.

In his concluding observations Dr. Harper makes the plea that all research workers in psychology should be making, that psychologists have not yet agreed on what is to be regarded as adequate evidence. This inevitably retards the progress of fundamental research, a disadvantage that the physical sciences do not possess to such a degree, and in reading a new contribution in any field of experimental psychology it is painful to see how difficult it is for work to be carried forward on the shoulders of what has gone before. J. F. T.

The editors acknowledge receipt of the following book for review:

Tables for Aptitude Testers (The Operating Characteristics of Aptitude Test Batteries.)

A. G. ARBOUS.

National Institute for Personnel Research, South African Council for Scientific Research, 1952. 86 *pp.*

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OPERATIONAL RESEARCH COURSE AT BIRMINGHAM UNIVERSITY

A TWO weeks' residential course on the use of Operational Research in increasing productivity was held at the Institute for Engineering Production of the University of Birmingham from 30 November to 11 December, 1953. The joint chairmen were Professor T. U. MATTHEW, who had organized the course, and Mr. R. T. EDDISON of the British Iron and Steel Research Association. It is believed to have been the first course of its kind in this country. Its aim was to provide an opportunity for review and discussion by industrial managers, senior production engineers and operational research specialists, of the techniques used and problems encountered in the use of operational research in increasing productivity in industry.

The course was attended by 26 members from a wide variety of industries throughout the country. Some members were from management, some were operational research workers, others were specialists in parallel techniques, such as industrial engineering and work study. The first speaker was Sir CHARLES GOODEVE, Director of the British Iron and Steel Research Association, who spoke on the *design of operational research*. He referred to operations in industry as being a series of decisions which lead to actions, which in turn are followed by further decisions. Operational research involved the application of scientific methods in such operations. In scientific method, five stages of the investigations can normally be defined. First, the defining of the objectives; second, the collection of observations; third, the analysis of the results; fourth, the drawing of conclusions from the analysis; and finally the testing of the conclusions. Quantitative methods are usually involved but not always. The operational research approach had common characteristics in a wide variety of fields.

The second speaker was Dr. T. E. EASTERFIELD of the Department of Scientific and Industrial Research, who spoke about *operational research and productivity measurement*. He described productivity as an index, being the ratio of output to input cost measured in either real or monetary terms. He described operational research as scientific research into the operations of a going concern, carried out for and in co-operation with the executives of that firm. He stressed the importance of the understanding of the objectives. He outlined four areas for the use of productivity measurements; these were first, to compare one factory or time with another; second, to study firms with extreme values of productivity; third, the establishment of targets; and fourth, comparing the values at different firms.

Other speakers included Mr. L. H. C. TIPPETT, who described some of the *work of the Shirley Institute*, particularly their productivity studies which provided firms with an objective basis for comparing their productivity with others. He described a number of simple statistical techniques and also referred to the snap reading method, which was developed by his Institute for taking observations in factories. This method is sometimes called the ratio delay or activity ratio method and its mathematical basis was elaborated by Dr. E. A. G. KNOWLES of Birmingham University.

Mr. D. J. DESMOND described some of the statistical concepts which form a basis for *methods of sampling inspection*. He gave examples to tell how the inspection system could be modified, so as to minimize the total cost when consideration is given to the rising costs of inspecting and the falling costs of defectives as the efforts spent on inspection is intensified.

Mr. C. A. OAKLEY of Glasgow University discussed *the human factors* affecting productivity. He referred to the processes of learning and training and stressed the importance of fatigue as an industrial problem, urging that further studies be made of environmental conditions, such as light, heat and noise. He pointed out that there could be wide differences between results obtained from experiments in the factory and results obtained in practice. These differences are due to operational factors which cannot be ignored.

There followed a series of speakers who described their experiences as *operational research workers in industry*. The first of these was Mr. H. R. WATKINS of Courtaulds Ltd. He described a number of problems at their Greenfield factory which had been resolved by the use of a variety of statistical techniques. He was followed by Mr. J. MURDOCH of the U.K. Time Corporation Ltd. who described some of the work for which he had been responsible as Operational Research Engineer at the English Electric Co. Ltd. These problems mainly concerned the layout of machines in the engineering workshop and the operation of the cranes serving the cupola.

Mr. A. W. SWAN of Courtaulds Ltd., considered that operational research had grown out of production engineering by the addition of new techniques. He also stressed the importance of the position of an operational research department in the organization. It was essential that it should thoroughly understand managerial policy and could act rather in the nature of an internal consultancy. He described the setting up of the Statistical Department at the United Steel Co. Ltd., and later at Courtaulds Ltd.

Dr. D. G. R. BONNELL of the Building Research Station described studies which had been undertaken to determine and

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evaluate the utility of tower cranes in the building industry. This work had led to the introduction of several hundred tower cranes into the British building industry and to two or three companies starting to manufacture tower cranes, within the short space of two years. Mr. A. T. HARDMAN of Humber Ltd. also emphasized that the leader of an operational research department must have a clear concept of the company's policy. At the same time it was essential that he should fit neatly into the management structure. In the Rootes Group different problems were tackled at each factory. At Humber Ltd. the first problem was the cost of quality. Poor quality leads to excess cost at three stages: firstly scrap, secondly rectification, and thirdly returns under guarantee. Generally a fault which costs 6d. as scrap, costs 1s. 2d. to rectify and 2s. for replacement under guarantee. These three costs were grouped together as decision cost, and they could be balanced against the cost of inspection. In the Rootes Group this sort of work was done through panels which included the technical people on the job.

There followed three speakers who dealt with special topics of operational research. The first of these was Mr. A. D. VAN REST, Ministry of Supply, who talked about *marshalling, queueing and storage problems.* The essential assumption in the solution of these is that although variability exists, it arises from a large number of different causes and these taken together can be regarded as having statistical stability.

Dr. F. HAHN of Birmingham University, outlined the possible areas of usefulness of *linear programming* by reference to a simplified version of the minimum cost-adequate diet problem. He said that the theory of linear programming is comparatively well developed; the need now is for practical experiments, to discover user applications. Computation is difficult and will usually require the use of an electronic computor.

Market research has been going on since industry began. Mr. J. C. HARVEY of Cadburys Ltd. described it as it now is; a specialized study into problems of sales forecasting, market planning, product development and the value of advertising. One of the main problems is that management decisions are usually required quickly whereas research takes a long time; it must therefore be designed so as to build up a store of information on which a decision can be reached quickly when required. Research is usually based on either continuous survey or "ad hoc" surveys applied to a random sample of consumers. Consumer panels have largely been abandoned owing to the conditioning of consumers that may take place.

Mr. E. C. WILLIAMS of the Admiralty was the last speaker and he dealt with the subject of *education and training for operational research*. He did not consider that operational research was basically something new; what was new was the importance of it. The most essential quality for a successful practitioner was a flair for the job; this was basically similar to that required for ordinary scientific research. If present it could be brought out by training. Other necessary qualities are insight, ability to do things the simple way, charm and ability to express ideas. He did not consider that operational research was yet ready for an extensive programme of formal training. In his experience the expertise required included mathematical ability up to elementary differential equation, simple statistics, probability theory, theory of communication and information, cybernetics in a general sense, and some physics and chemistry of energy exchange.

During the Course four after-dinner speakers dealt with the subject broadly. These were Professor P. M. S. BLACKETT, Imperial College, who referred to his experiences in wartime operation research. Professor S. ZUCKERMAN, Birmingham University, discussed operational research and scientific progress. Dr. A. KING, Department of Scientific and Industrial Research, talked about developments in O.E.E.C., and Dr. O. H. WANSBROUGH-JONES, Chief Scientist of the Ministry of Supply, discussed possible fields for its development in Government administration and the nationalized industries.

The admixture of members with widely different experience, both managerial and technical, was found to present great advantages in the formal and informal group discussions which formed an important feature of the course. It presented some difficulties, however, in determining the syllabus particularly in deciding how much knowledge of the elementary statistical and probability theories could be taken for granted. There was some debate at first, on the grounds that operational research appeared to be nothing more than an extension of earlier techniques, such as industrial engineering. By the end of the course it appeared the meaning of operational research had been clarified for those with managerial interests, while most of those with specialist interests felt that their horizon had been broadened.

A number of lessons have been learnt from this course and advantage will be taken of them in planning future courses of this type. Two more such courses are already arranged for April and June, 1954, and these will again be organized on a two-weeks residential basis at the Institute for Engineering Production.

R. T. E.

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